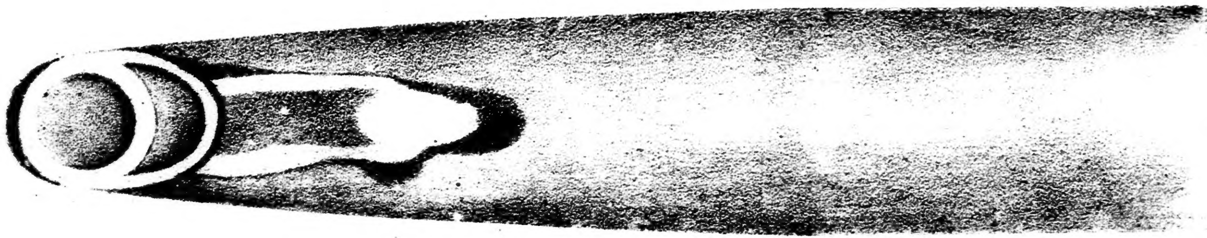
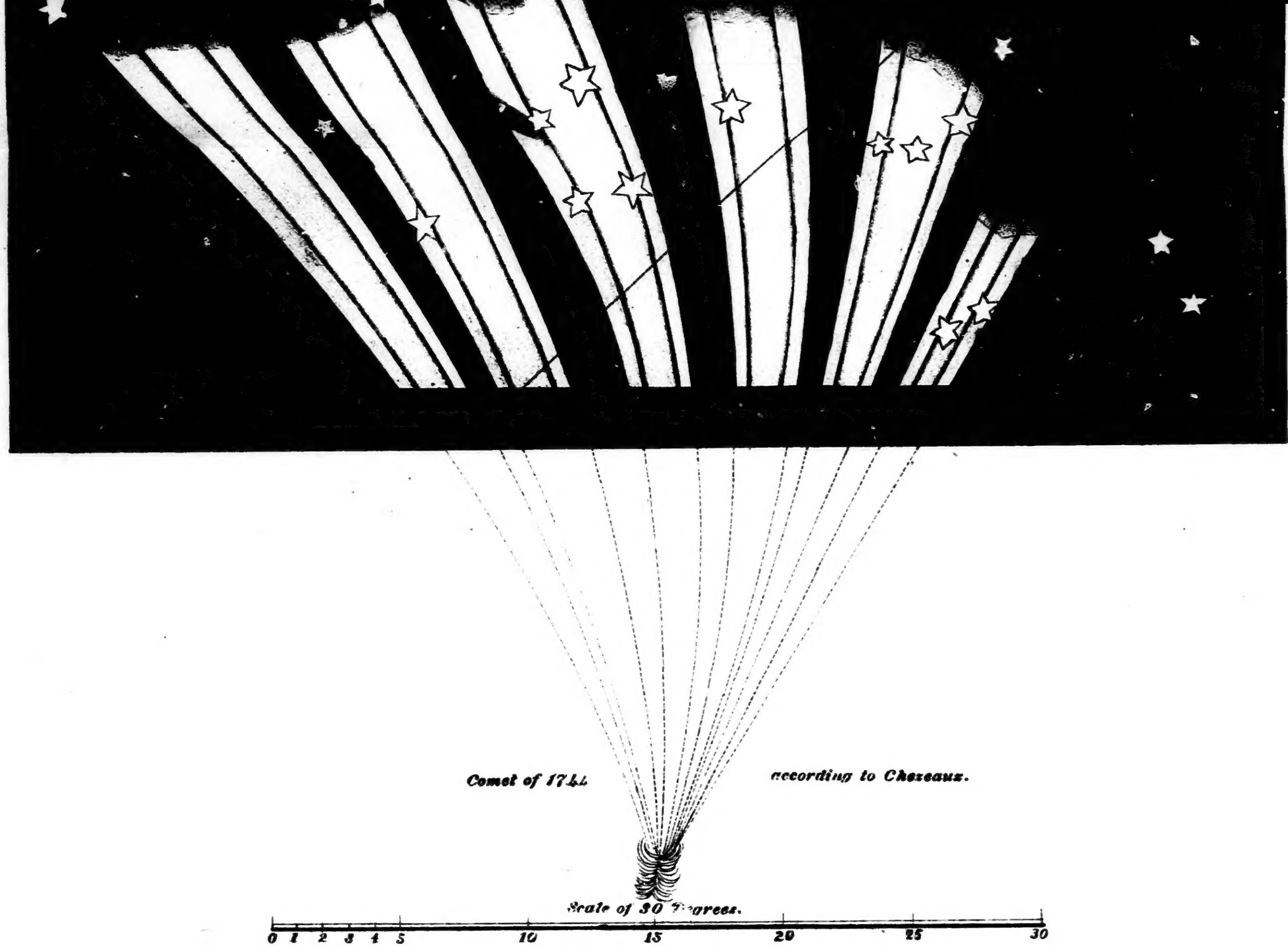
ASTRONOMY.

Fig 106.



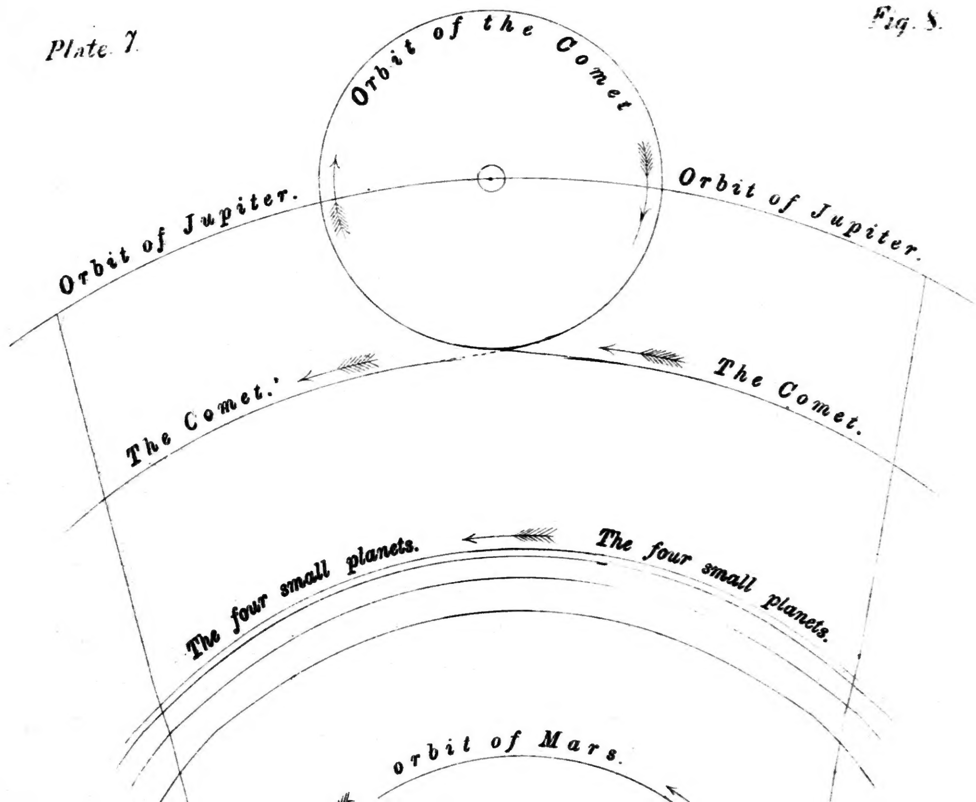
Comet of 1680. Hist. Celeste of Lemonnier.



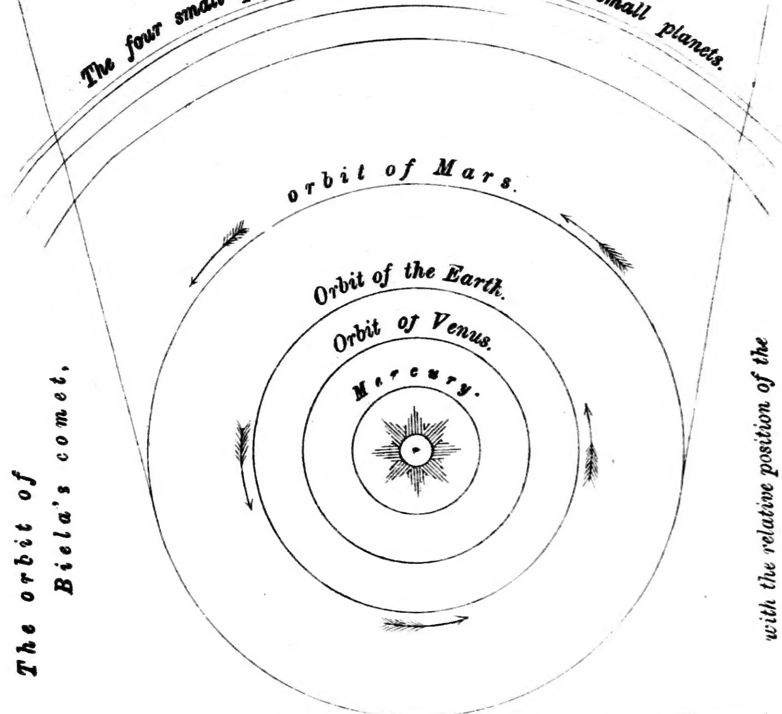
From the Encyclopedia Britannica.

Plate 7.

Fig. 8.


Orbit of the Comet
Orbit of Jupiter.
Orbit of Jupiter.
The Comet.
The Comet.
The four small planets.
The four small planets.
orbit of Mars.

The orbit of
Biela's comet,



with the relative position of the
orbit of the Earth.

The period (solar period) of the comet is 900 days (nearly $2\frac{1}{2}$ years).

***The terrestrial period** is at present reckoned, according to the theory of cometary orbits, at 2,410 days. This we consider, according to the law of gravitation, represents 3 orbital returns of the comet. Wherefore 2,410, divided by 3, equals $803\frac{1}{3}$. But the earth requires 145 days to complete the seventh (annual) orbit, and taking the velocity of the comet at one-half that of the earth, 2,410+290=2700. And 2700, divided by 3, equals 900 days, which is, therefore, the solar period.*

See page 16 et seq

(4.) *CENTRIFUGAL FORCE & GRAVITATION.*

COMETS

AND

The Theory of Cometary Orbits.

BY

JOHN HARRIS.

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INDEX.

INDEX OF PLATES.

PREFACE.

In the historical record of the younger days of the human race, the appearance of a comet was the occasion of wide-spread fear and anxiety; the portentous signal of the wrath of the Deity; the probable fore-runner of dire calamity, none the less alarming because its nature and the precise character of the impending catastrophe were alike mysterious and unknown.

In reading the narrative of the feeling with which such a natural phenomenon was regarded and the conduct by which that feeling was expressed, the young student of the present day, possessed of only a very elementary knowledge of physical science, is apt to think within himself . . 'the men of that age must surely have been foolish and superstitious in a surprising degree to be astonished and frightened at such a natural occurrence.' Doubtless we, older and somewhat more experienced students of physical science, are not likely to be so hasty in writing down and judging our ancestors as altogether foolish; nevertheless, we may err greatly and in the same direction, although not quite so superficially.

Let us briefly consider the case in the way of comparison:— For the reasonableness of a conclusion to be absolute, an absolutely perfect knowledge of the subject to which the conclusion pertains is requisite. Now such absolute perfection does not belong to human knowledge on any subject (unless, perhaps, in regard to some subjects or facts of a quite simple and elementary description). Therefore, in a human sense, reasonableness is dependent or relative. For example . . a man may have a very limited knowledge of a sub-

ject, and may come to a conclusion quite reasonable relatively to that limited knowledge; *i. e.*, his conclusion may be supported by his direct and indirect knowledge of the facts and be limited by the limited extent of that knowledge. On the other hand, a man may have a much more extensive knowledge of the subject and may come to an unreasonable conclusion; unreasonable because .. he allows undemonstrated theories and inventions of his own to occupy the place of fact, and bases his conclusion not upon his sound limited knowledge of the subject, but upon the unsound combination of that which is true with that which is false.

In the appearance of a comet, our forefathers contemplated a strange, and to them an alarmingly mysterious phenomenon. An apparition in the heavens, almost, if not quite unprecedented,* presents itself suddenly to their astonished vision. There must be a cause...Can any known natural cause be assigned to reasonably account for the phenomenon? No; the circumstance is apparently quite unique and irreconcilable with the observed facts belonging to astronomy. The character of the celestial visitant evidently differs greatly from that of the stars and planets. It appears suddenly, spreads its luminous signal over a considerable space in the heavens and, after remaining very conspicuous for a certain time, the menacing apparition suddenly disappears. There must be a cause...Can any known cause be reasonably assigned? Yes; one, and one only. It is known that the Creator is omnipotent over the laws of nature; it is known, by the ever present facts of creation, by

* Supposing tradition, or even the memory of the older men, to have informed them that the visitation was not unprecedented, the accounts of the former appearance would be mixed up with the fears and prognostications of calamity which it inspired, and, probably, some event of a disastrous character, which had afterwards taken place, would be connected with it as its consequent.

tradition and record of the most reliable description, and by the teaching of the inner intellectual consciousness (reason) that God the Creator has power, if He will, to cause such extraordinary phenomenon. But an extraordinary exercise of the divine power suggests some particular and important purpose. What purpose is it most probable that such a witness is intended to notify? It is a signal evidently, but of what? Its aspect is menacing...its form and appearance suggest danger. It is most probably a signal of the wrath of the Deity; but again, for what? Many individuals are aware that they have individually been doing what they knew to be wrong; have been disobeying or, perhaps setting at defiance His moral laws, and feel that they are criminal in the sight of God; but it does not seem reasonably probable that the crimes or sins of a few individuals would be considered of sufficient importance to occasion such an extraordinary manifestation of the divine power. The nation! Ah..the nation feels conscious that it has been doing wrong; has been violating the laws and commandments of God; or, at least, has been neglecting to fulfil some part of that which it knew to be its duty to Him. Ah; that is the explanation: the nation has angered and provoked the wrath of God and this apparition is the signal that punishment is about to be inflicted.

We know now that our ancestors were mistaken in fact with respect to the nature and purpose of the comet's appearance. It was not a miraculous portent having express relation to the sinfulness or misconduct of a nation. It was a natural phenomenon, quite of the same character as the appearence of a planet or a star.

But does it follow, therefore, that the conclusion of our ancestors was superstitious and unreasonable? Not at all. We opine that the more carefully the case is considered, the more certainly it will appear that their reasoning, assuming it to have been as stated, was essentially sound

on both the important questions involved. (1) Whether it be within the power of the Creator to cause an exceptional and supernatural phenomenon (such as this was supposed to be) to present itself; or, to state the question more generally in other words, .. whether the Creator be the living Omnipotent God, possessing the power to control and impose such laws upon the Natural world as He pleases? (2) Admitting the existence and omnipotence of the Creator, the second question is . . Whether there be supervision and direct supernatural intervention, general or special, by Him in the affairs and arrangements of the Natural world?

The first question belongs pre-eminently to general and physical science. It is a primary or fundamental question which all students of Science, especially those who break ground for themselves and become patient and persistent cultivators of the soil, must sooner or later meet face to face and consider with careful and earnest attention. What then, is the general conclusion or judgment arrived at with respect to it? We have no hesitation in replying that a very large and overwhelming majority of the men of science belonging to the present, to the immediate past, and to that earlier age of science preceding the immediate past, agree in affirming the proposition here stated in the form of a question. Of the great names inscribed on the muster-roll of Science a very large majority are those of men who have decidedly expressed their conviction that the Creator is possessed of such omnipotent supernatural power, and who have therefore indirectly expressed their belief that a material or immaterial cometary apparition might or may be caused by the Will of God with a special and express purpose.

The second question, as to continual or occasional supervision and supernatural intervention by the Creator in the natural world, is also one which is answered in the affirmative by a vast majority of the educated men of

our own time. All those who profess any form or system of christianity agree in such affirmative answer; for a profession of christianity is manifestly inconsistent with a disbelief as to such spiritual supervision and intervention; christianity being, both directly and indirectly, based upon such belief.

We find therefore that the reasoning of our ancestors, and also their conclusion, taking into consideration their very limited knowledge of facts belonging to physical science, is justified by the increased experience and knowledge since acquired by the human race. How stands the case on the other side of the comparison, viz., with regard to ourselves, the present more highly civilized and educated representatives of the human race? What is it that we are in effect now taught with respect to a comet and to the nature of a comet? That it is not a mass of aggregated matter obedient to the law of gravitation; nor is it an animated, intelligent being; but a mysterious phantom endowed with instinct and capability of the most extraordinary and surprising description, by virtue of which it is enabled to leave the dominion of the sun and, setting at nought the laws of matter, to retire to the most remote regions of space; and yet, after the expiration of a certain time, notwithstanding its then enormous distance therefrom, it becomes again cognizant of the existence and influence of the sun, and, guided apparently by the strange instinct of which we have spoken,* and quite inattentive to the attractions of other stars and stellar systems, it usually, although not always, finds its way with direct and unerring precision, back again

* It will be understood that the application of the term instinct to the guiding principle under which the comet of the present doctrine performs its eccentric migrations is ours, and is not so used in the astronomical works to which we allude, but we so apply it because instinct is, in fact, the only guiding principle known to science in connection with the material world which can be assigned to satisfy the requirements of the doctrine.

to the immediate neighbourhood of the central body of our particular stellar system.

Now this is substantially and essentially the present doctrine as laid down in the best and most highly reputed treatises on astronomy, and we opine that the ancient representative of human education, if brought directly into argument with us, would be entitled to say: 'Our explanation is, you are obliged to admit, not in itself unreasonable: it is true we have not explained the nature of the comet itself because we have not, and do not pretend to have, knowledge of it, but your presumptive explanation is quite unreasonable and untenable. If your comet be wholly spiritual and immaterial your explanation should show that the action or behaviour of other spiritual existences is regulated by a similar strange instinct, but if your comet be in any degree material why is it not subject to the general laws of the material world? You have had more time and better opportunities to observe these apparitions than we have had, and we may believe that you have, as you say, found out that they are recurring phenomena, reappearing with regularity after definite periods of absence. This is well, and may be eventually useful as an addition to the knowledge of the facts belonging to the phenomenon, but, in a reasonable sense, you have confused your statement of a fact by mingling it with certain extravagant, unsupported, and incredible suppositions, and you have really given no philosophical explanation of the case.

CHAPTER I.

THE THEORY OF COMETARY ORBITS.

INTRODUCTORY OBSERVATIONS.

As already stated, it is not permissible to entertain the supposition that a planet or other mass of aggregated matter, revolving around the sun (or other centre) under the influence of gravitation, can suddenly divest itself of that influence;* consequently the hypothesis which supposes the orbital path of a comet to describe a parabola or a hyperbola must certainly be erroneous. But it was also explained in the earlier part of this work, that the deviation from a circle in the orbital motion of a planet revolving around a centre of gravitation is of the nature of an oscillation or vibration, which is kept under control and restricted in amount, by the gravitating influence in the one direction and by the centrifugal force in the other. If this teaching is correctly understood, it will become apparent, on attentive consideration, that, although the elliptical orbit of a mass of matter (planet) may vary as to the eccentricity of the ellipse described by its path, such variation can be only within certain narrow limits determined by the particular circumstances of the case; the favourable conditions for the development or permanence of a larger amount of eccentricity being a great angular velocity and a short distance from the centre of gravitation; whereas, under the reverse conditions,

* Part First, page 55; also Part Third, page 24, *et seq.*

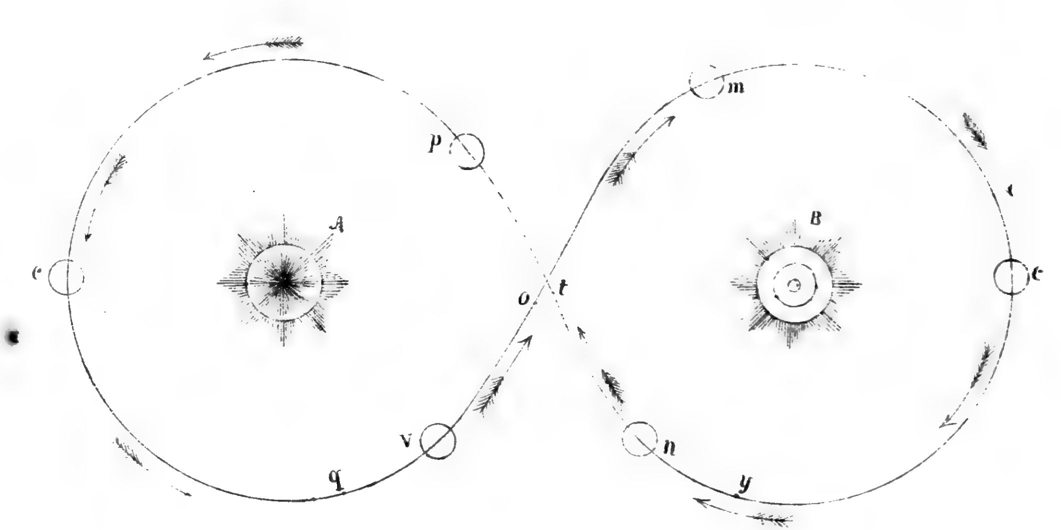
viz., an orbit of much greater diameter and proportionally lesser angular velocity, the deviation from a circular path will be so much less. It is true, a perturbing influence may interfere and cause a considerable increase in the deviation; but this increased deviation can only become permanent, as a constant (periodical) oscillation, if the conditions are favourable; otherwise, the effect of the perturbation (if permanently any) would be to modify the average distance from the centre of gravitation throughout the entire orbit. It will therefore also follow that it is not allowable to attribute to a planet or comet, revolving around the sun as its primary centre, an elliptical orbit having a very great degree of eccentricity, and of which, therefore, the aphelion distance is very much greater than the perihelion distance.

(1) *The compound sidereal orbit.*—We say that such an hypothetical orbit is inadmissable because it is irreconcilable with the law of gravitation. It is, nevertheless, quite possible for a planetary or cometary mass of matter to enter the solar system, and being within the sun's gravitating influence, to approach the sun, and even to make a partial revolution about the sun, and then to depart or return to another system.

To explain this more particularly we refer to Fig 1, (Pl. 1,) where *A.* represents the *sun,* and *B.* represents the central *star* of a neighbouring system; *C.* is a comet or cometary mass of matter; *m. y. n. p. q. v.* is the comet's supposed orbit. From the place *m.,* the comet moves in the direction of the arrows through the circular arc *m. c. n.,* having *B., the star,* for the centre of gravitation; having arrived at the point *n.,* the direction of motion is the tangent to the arc, viz., *n. o.* Now if *C.,* the comet, were

Plate 1.

Fig 1.



strictly a member of the system belonging to *B.*, and confined to that system, that is to say, beyond the influence of any other gravitating centre, then, the influence of *B.*, being counteracted only by the centrifugal force of the moving comet, would restrain it from deviating out of the circular path; but the distance of the comet *C.* from *B.*, is so great that, when it has arrived at *n.*, the influence of the sun *A.*, has already begun to act upon it, and by counteracting the influence of *B.*, lessens the effect of the latter; consequently the motion of *C.* deviates outside the circle and towards the tangent; so that the orbital path *n. t.* is intermediate between the arc of the circle and the tangent. At this point, being at about the half distance between *A.* and *B.*, their opposing influences are about equal and *C.*, therefore, moves in the direction of the tangent. The comet is now rapidly receding from *B.*, and approaching *A.*; when it has arrived at the place *p.*, the comparatively feeble influence of *B.* will be effective only in retarding the motion and diminishing the velocity, which will have just previously increased in consequence of *A.*'s influence during the approach of the comet towards *A.*, whilst moving from *n.* to *p.* After passing the place *p.*, the influence of *A.* will be alone effective in restraining and governing the motion of the comet, which will therefore move in a circular orbit round *A.*, until having passed *q.*, it arrives at *v.*, the point corresponding to that of *n.* in the neighbouring system. The conditions will be now similar to those preceding, when the comet was at *n.*, and moving towards *A.*, only that the relation of the two centres of gravitating influence to each other in respect to the comet will now be reversed; and the comet will now leave *A.*, and approach *B.*, moving through

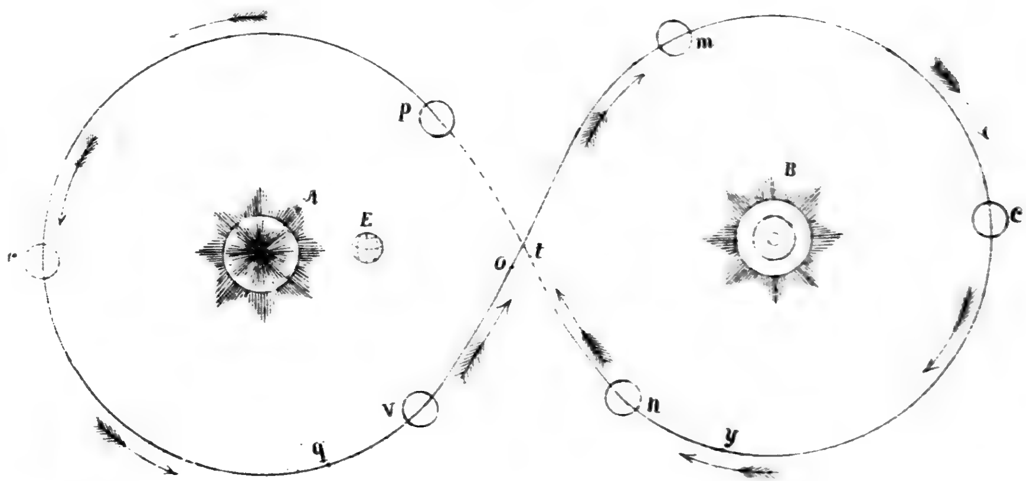
the compound curve *v. t. m.*, which is similar to the curve *n. t. p.*, through which *A.* was approached. From *m.* the comet will again traverse the same compound orbital path; and so on continuously, moving in the direction of the arrows.*

If now we assume that such compound orbital path of a siderial comet may be in a plane vertical to that of the solar system, or in the same plane, or in a plane oblique at some angle to the plane of the solar system; it will be at once apparent that to a spectator observing the comet from the earth the difficulty of correctly determining the orbital path by observation must be very great. Fig. 2 (Pl. 1) may serve to convey a clearer idea of the difficulty. *E.* represents the earth, and the orbit of the comet is supposed to be vertical to the ecliptic (or to the plane of the sun's equator). If the comet, on entering its solar orbit from *t.* in the direction *t. p.*, became visible from the earth, the orbital motion of the earth would be *apparently* transferred to the comet, which apparent motion, in the reverse direction to the actual motion of the earth, would combine itself with the real motion of the comet; and thus give the appearance to an observer on the earth of an approach to the sun in an oblique direction.

The law of gravitation permits us to suppose that a mass of aggregated matter may thus have its motion con-

* This explanation in respect to the uniformity of the comet's distance from the centre of gravitation is provisional only: it will be seen hereafter that our theory supposes an expanding compound orbit, viz., that the comet on leaving the one orbit and entering the other approaches nearer than its average distance to the centre of gravitation, and then commences and continues to recede (spirally) from that centre, until it (the comet) again enters the former orbit where, in like manner, it approaches that centre and then commences to recede, and so on. *See illustration and remarks, page 22.*

Fig. 2.



trolled and regulated by two distinct centres of gravitating influence; nor are we prevented from supposing that the orbit may be yet more complex, and that three or even several systems may be traversed in a similar manner and in obedience, as already explained, to the recognized law of gravitation. Fig. 3 (Pl. 2) shows the orbital path of a comet which is supposed to be controlled by three distinct centres of gravitating influence; the arrows and the explanation already given will sufficiently indicate the manner in which the orbit is compounded.

In either of these cases it is evident that the comet would be periodic; and if, in any part of its orbit, it approached the earth to within visual distance, the time of its return, after several such visitations had been observed and noted, might be safely predicted.

(2) *The compound solar and planetary orbit.*

It may be objected to the foregoing that there are certain comets which are known as belonging altogether to the solar system, of which the periods are too short to admit the supposition of their travelling beyond the influence of the sun, and of which the orbits and elements have been calculated on the eccentric hypothesis, and the results of the calculations confirmed and verified by actual observation. But a planet, which is secondary to the sun as the general centre of the system, may be, if of sufficiently large size, primary to bodies of much less mass, as for instance the earth to the moon, or either one of the large planets to the satellites which revolve about them as their centre of gravitating influence. Evidently therefore, the law of gravitation allows us to suppose that a planet of large size, which, as a planet, is secondary

to the sun, may also serve together with the sun as one of two primaries controlling the motion and determining the orbital path of a comet: the requisite conditions of the case being that the relative distance of the cometary body from the sun and from the planet is proportional to the relative masses of the sun and the planet. For example, in Fig. 4, (Pl. 3), *J.* represents the planet Jupiter, *S.* the Sun, and *C.* a cometary body: the comet's orbital path is indicated by the arrows. The conditions of this case will be essentially similar to those explained in the example of Fig. 1. In that example the two centres of gravitating influence were supposed equal; and in this, the mass of the sun is much greater than that of Jupiter, but the orbital distance of the body *C.* from the sun is assumed to be also greater than its orbital distance from Jupiter, in the same proportion; and therefore when the body in Fig. 4 arrives at (about) the point *m.* it will be essentially in the same case as at the point *n.*, in Fig. 1, viz.: the attraction of the planet, adding its influence to the centrifugal force, will in the first place cause a deviation towards the tangential direction outside the circular orbit; a little further on, the attractions of the planet and of the sun will be equal, and the body will move in the tangential direction, thereby receding from the sun and approaching the planet; thus when the point *n.* has been reached the more distant and feeble influence of the sun will operate only in diminishing the (increased) velocity, and the cometary body becomes a satellite of the planet throughout *n. a, p.*, about three-fourths of a revolution, until on arriving at (about) the place *p.* the former conditions are reversed, and the comet receding from the planet returns to its solar orbit *q. b. m.* It is

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Plate 3.

Fig. 4.

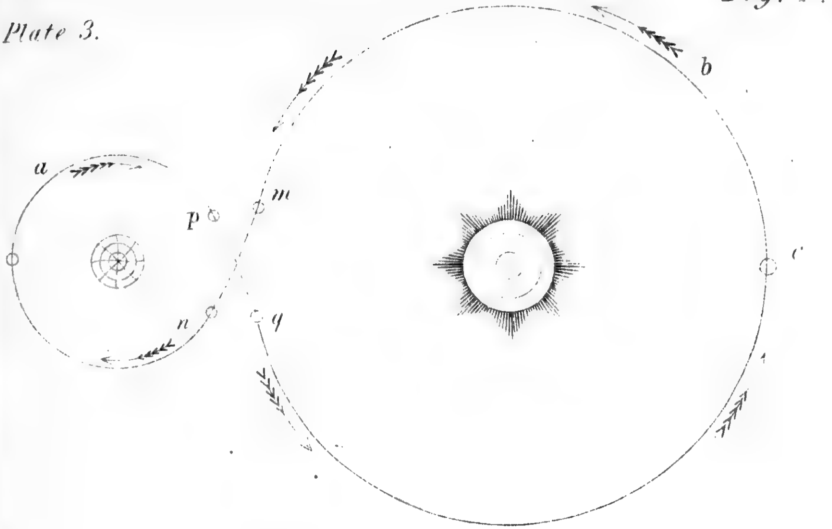


Fig. 5.

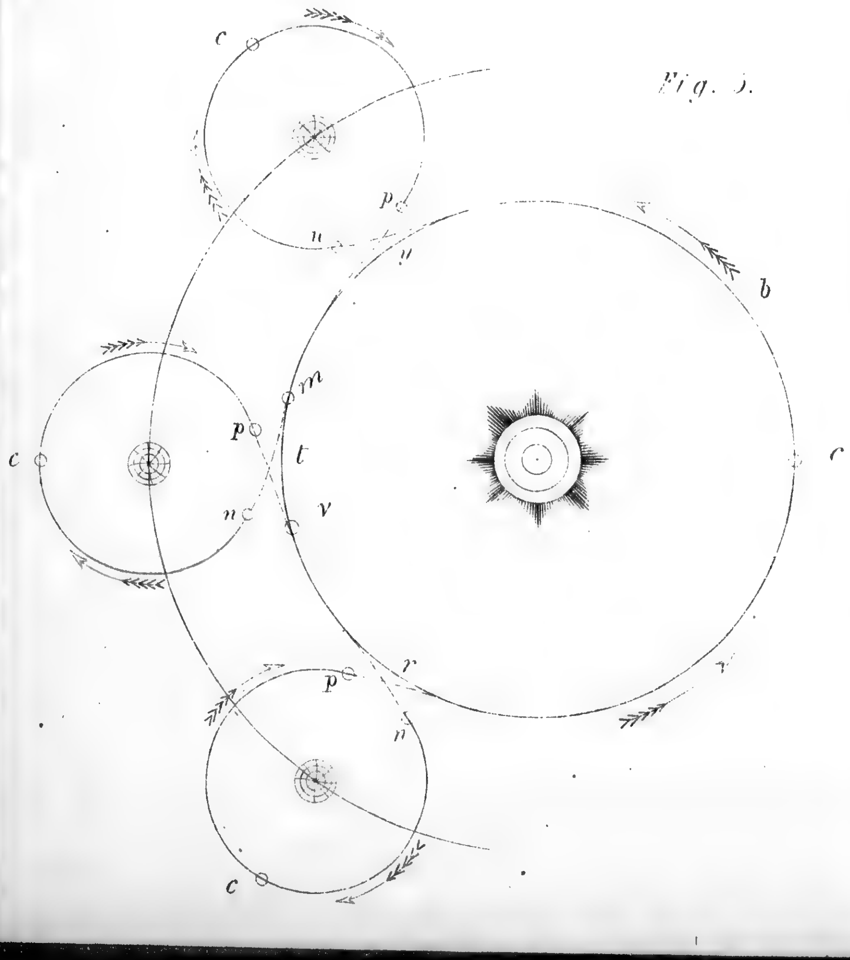
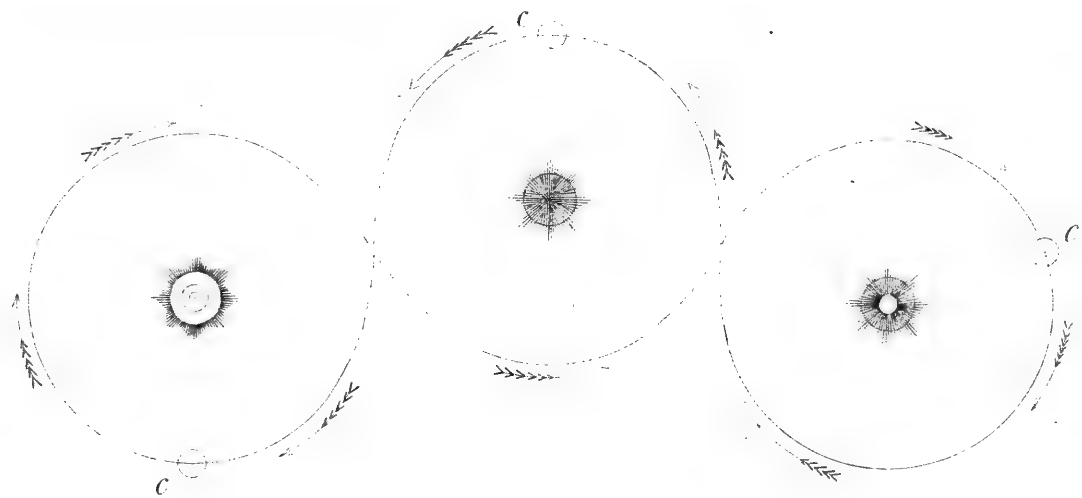


Plate 2.

Fig. 3.



true, the planet is itself in motion revolving around the sun; but this will only modify the orbital path of the comet in such wise that...if, on the one hand, the motion of the comet is in the same direction as that of the planet, it will have to overtake the motion of the planet before leaving its solar orbit, which will thus be, in the first place, increased; but, since the distance after leaving the planet and returning, will be so much less, the entire orbit, measuring from a definite (fixed) point will be the same; or on the other hand, if the orbital motion of the comet be supposed in the reverse direction to that of the planet, then the motion of the planet will become, in the first place, a deduction from the solar orbit of the comet; because the planet will then (so to speak) meet the comet, but this will again be compensated by the greater distance which the comet has to travel after leaving the planet. In this last case, where the motions are in the reverse direction to each other, the distance travelled by the comet in one complete compound revolution, proportionally to the orbital distance from the sun, would evidently be greater than in the first case where the motions are in the same direction; because in the first, the planet carries the comet, by so much, onward in the direction of its goal; and in the second case, carries it, an equal distance, back again towards the starting point. This will be readily seen by repeating the figure; thus in Fig. 5, (Pl. 3), we will suppose that, during the time required by *C.* to move from *q.*, through its solar orbit *q. b. m.*, the planet *J.* moves in its orbit from *t.* to *r.*; the comet *C.* will then require to continue in the solar orbit until having passed the point *q.* and having thus more than completed a revolution round the sun, it overtakes the planet and

returns to the planetary orbit at *n.*; or, on the contrary, if we suppose, during the same time, the planet to have moved in the opposite direction from *t.* to *y.*, the comet, before it arrives at its former place of departure in the solar orbit *m.*, will meet the planet and enter the planetary orbit, as before, at *n.**

However, having noticed this difference as theoretically worthy of remark, we will dismiss it as practically inapplicable, because the plan of the solar system does not, as we opine, admit of such reverse motion. We believe that all the celestial bodies under the particular government of the sun, whether called planets or comets, revolve around that central luminary in the same direction without any exception.†

It is known that the earth, which is much nearer to the sun, moves in its orbit with a proportionally greater angular velocity that the planet Jupiter; now, if we were at liberty to assume that the comet moved with a

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* It must be remembered, however, that the comet in becoming for a time a satellite of the planet, still belongs to the solar system and is still subject to the direct influence of the sun, which is now combined with the more immediate influence of its primary the planet. If the supposition of a possible reverse motion be entertained, the planetary orbit will be to some extent modified by the direction of motion of the comet relatively to that of the planet, because, referring to the figure (Fig. 5), in the one case, the motion of the comet, on entering the orbit, will cause it to approach, and in the other to recede from the planet, thus, in the first instance, increasing or decreasing the angular velocity and in either case resulting in an elliptical orbit.

† This does not include the case, proposed at page 12 *et seq.*, of a comet owing a divided allegiance to the sun as one of two or more centres of gravitation, and in which case the direction of the motion may be *reverse*.

considerably greater angular velocity than the earth, it is evident that, if the three bodies were relatively so situated at a particular time, the comet might be visible from the earth before entering the planetary orbit, and during the time of its revolution around the planet, the earth might pass the planet, and soon afterwards the comet returning to its solar orbit, and overtaking the earth might again become visible therefrom; but such would be an assumption which we are not permitted to make, because it would include an assumption that the matter of which the cometary body consists is subject to a law of gravitation differing from that law to which the earth and the other planetary bodies are subject; for if the law be the same, the angular velocity of the comet in its solar orbit, cannot be even so great as that of the earth; for example, let us suppose it equal to that of the earth; then since the radial distance of the comet from the sun is greater than the radial distance of the earth from the sun, the linear velocity of the comet must be greater than that of the earth proportionally to the relative distance; it follows that the radial distance being greater, the gravitating influence of the sun is less on the matter of the comet than on the matter of the earth; but the angular velocity of the comet is (by the supposition) the same as that of the earth, and consequently, the centrifugal force influencing the matter of the comet is greater than that influencing the matter of the earth; therefore under the supposed conditions, the comet would necessarily recede to an orbital path at a greater distance from the sun, whereby, the angular velocity being reduced, the requisite counteracting equality between the gravitating and centrifugal forces would be established. *Part First, p. 44.*

(4) *Terrestrial-and-Solar Comets.*

If we now suppose the earth to take the place of the planet Jupiter in a case similar to that illustrated in Fig. 4; the question as to whether or not the comet so approaching and partially revolving around the earth at the distance of a few million miles would be visible from the earth must depend upon the mass (size) of the comet and its luminous or non-luminous character.

Let us here again consider how completely such a theoretical *terrestrial-and-solar* comet would fulfil the observed phenominal conditions frequently witnessed from the earth.

Referring to Fig. 4, (Plate 3), the comet entering the terrestrial orbit from *m.* towards *n.* becomes visible: what is its velocity? Since its radial distance from the sun is not much less than that of the earth, its angular velocity in the solar orbit must be nearly equal to that of the earth. If, therefore, in its terrestrial orbit, its distance from the earth were not greater than that of the moon from the earth, we should have the linear velocity defined as rather less than the linear velocity of the earth compared with the linear velocity of the moon, and which is about 31 times greater. In such case the comet would travel through its terrestrial orbit in rather more than one day and then appearing to pass through its perihelion as it crossed the sun, would be again seen as it departed in its solar orbit from *q.* towards *C.*

But if instead of supposing the distance of the comet in its terrestrial orbit to be the same as that of the moon we suppose it to be about 10 times that of the moon, we shall then have the comet, at a distance of two and a half million miles occupying about 12 days in perform-

ing its terrestrial revolution, and then taking its leave of us, until it again, after a long interval, overtakes the earth and repeats its terrestrial circuit. How long would that interval be? Supposing the radial distances from the sun of the orbits to be, respectively, for the comet 90 million, and for the earth 92½ million miles, and the linear velocities to be equal, the angular velocity of the comet would be greater than that of the earth in the proportion of 92½ : 90. It would therefore gain two and a half (solar) revolutions in 92½ revolutions, which is equivalent to the gain of one revolution in 37 revolutions. Consequently at the expiration of about 37 years, the comet would again overtake the earth and become visible. It would accordingly be classified as a comet of 37 years period. The compound cometary orbit, as we have (to avoid complexity) illustrated and considered it so far, is subject to certain deviations in respect to the uniformity of its distance from the respective centres of gravitation in different parts of the orbit. Referring again to Fig. 4, and supposing the comet to have almost completed the circuit of the planet and to have arrived at the place *p.*, we have to consider that in consequence of the great angular velocity in its terrestrial orbit, the path of the comet must be in the curve of a spiral expanding outwards from its centre of gravitation —the planet. Consequently the comet is in such wise already receding from the planet; but now, to the effect of the centrifugal force is added that of the sun's direct attraction, and the result is a path not through the point *q.* and in the arc of the circle *q. C.* but considerably nearer to the sun than *q.* and in the arc of a circle (ellipse) having a considerably lesser radial distance

from the sun than *q. C.* But now, again, the comet is travelling in an orbit wherein the intensity of gravitation and the centrifugal force are not in equilibrium, because the angular velocity of its revolution must have become greater than that belonging to its average distance, proportionally to the distance by which it has approached the sun. Hence, the comet is now moving in the curve of a helix (ellipse)* expanding outwards; when, therefore, the comet arrives at *b'.* it has receded to a greater distance from the sun than when at *C.*, and, again, when it arrives in the neighbourhood of *m.* it is still more distant from the sun. The result of this modifying influence is indicated in Fig. 6, as the compound expanding orbit, whereby, if we suppose the planet to be the earth, we become still better able than before to appreciate the almost sudden manner in which a comet observed by aid of the telescope at a great distance, appears to rush into comparative proximity to the earth, and then commences to recede very gradually at first, as the terrestrial orbit expands its curvature, and after a time (of 10, 20 or 30 days, perhaps,) very rapidly, as the sun adding its power to the centrifugal force overcomes the terrestrial gravitation, and thus, finally, the comet appears to recede with a suddenness and velocity similar to that of its approach.

NOTE.—*Fig. 8 is a repetition on a larger scale of Fig. 6; and Fig. 7 exhibits the similar correction applied to Fig. 5, viz: the compound expanding orbit of a sidereal comet.*

* The fractional curve or arc of a helix may be considered identical with the corresponding curve or arc of an ellipse; but in one, the expansion continues in each succeeding arc; whereas, in the other, centrifugal expansion having reached a certain limit, is succeeded by a corresponding centrepetal contraction, so that the figure becomes finite and complete.

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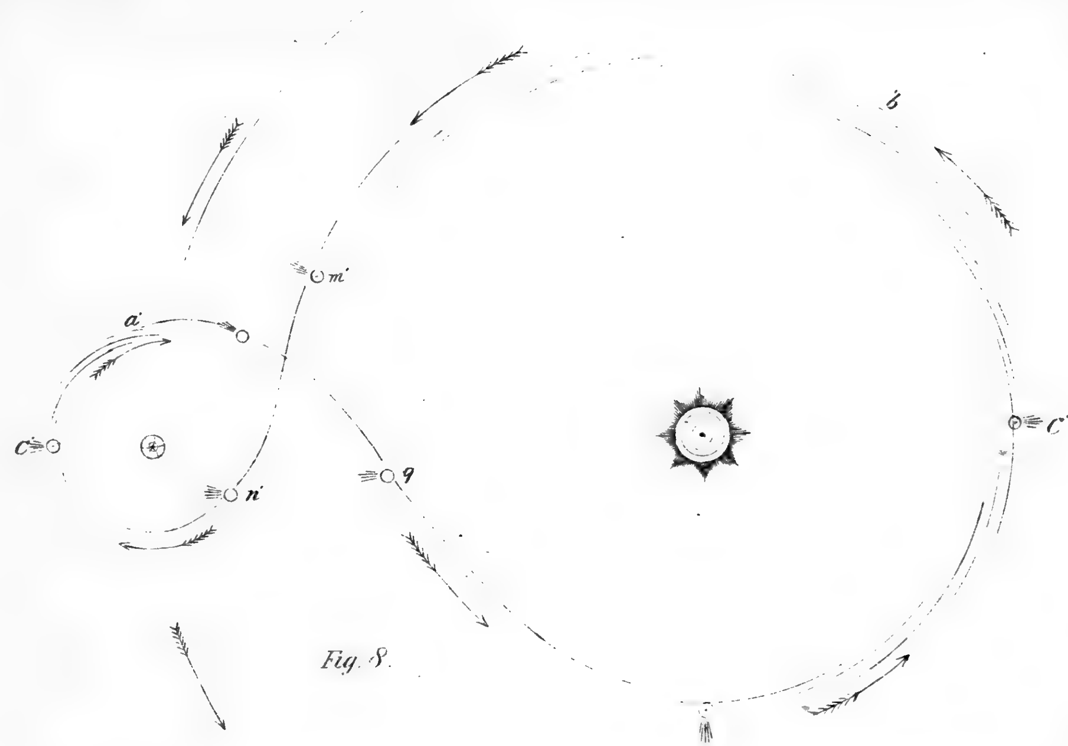

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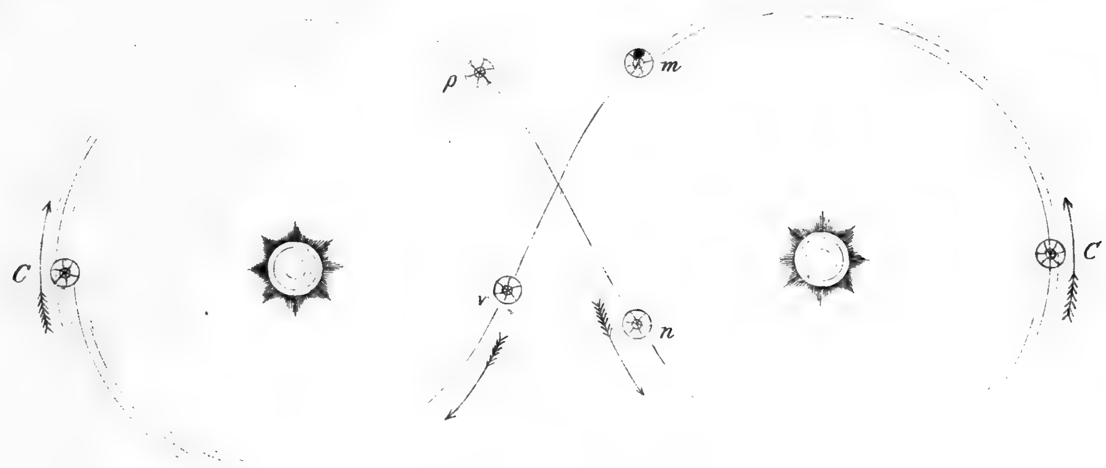
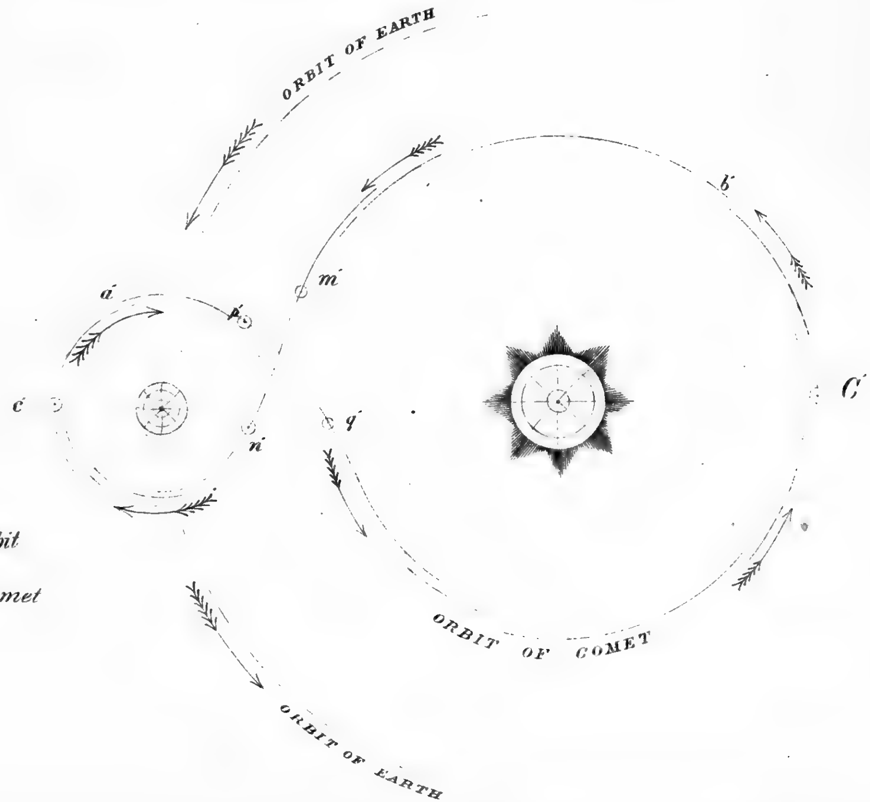


Fig. 7.

The Compound expanding orbit of a Sidereal Comet.

Plate. 4. Fig. 6.



The Compound expanding orbit

of a planetary-and-Solar Comet

CHAPTER II.

THE COMETARY PHENOMENA.

(1) *Theoretical consideration of the phenomena.*

The peculiar appearance of the *coma*, and the luminous characteristic of the train or tail of many of the comets, are appearances of which no satisfactory explanation has been given. With respect to the first, we think that a careful consideration of the evidence which geology furnishes, as to what was certainly the condition of the earth at a time antecedent to the existence of animal and vegetable life thereon, will enable us to understand the nebulous appearance of the *coma* and the comparatively small size and solid appearance of the *nucleus*. Geological theories explaining the primary condition of the earth, appear to be at present in a somewhat incomplete and crude state, contravening more or less the known physical laws of matter. The explanation now perhaps most generally accepted is to the effect that the entire mass, including all the varieties of matter compounding the earth as it now exists, was originally in a state of vapor. This entirely vaporous condition of the earth is supposed to have been succeeded by a liquid nucleus occupying the central part of the vaporous sphere and consisting of the denser varieties of matter in a molten state; after a time, loss of heat having been caused by radiation, a crust is supposed to have been formed on the surface of the liquid (fluid) nucleus, which, being subsequently acted upon by volcanic agency and earthquakes, acquired stability as the cooling

process went on, and eventually became fitted for water to remain on its surface, and for the support of vegetable and animal existence. Now this hypothetical explanation in the first place takes for granted that all those varieties of matter, whether compound or elementary substances, which are now known to us in the solid state may be volatilized by the influence of heat. The evidence of chemistry, in the present state of the science, does not certainly do more than allow of such a supposition as a possibility; it would be at least as reasonable, on chemical grounds, to suppose that many of these varieties of matter now recognized by us as elementary are not *in fact* elementary, and would be decomposed and separated into their elements if exposed to the exceedingly high temperature contemplated; and it might be assumed with a greater measure of probability, that even the intense heat supposed would be unable to vaporise (volatilize) or even to liquefy some of those substances now known to us as solids, but that some of them would resist liquefaction even at the highest temperature. But allowing, for a moment, the possibility that intense heat, under favourable conditions, might liquefy and volatilize all the solid forms of matter, yet we find the hypothesis tacitly assuming that the entire mass or quantity of matter compounding the earth has not undergone augmentation; but that, whether in its present partially liquid and partially solid and gaseous condition; or, as formerly, in a partially or wholly vaporous state, the aggregate quantity of matter has remained the same. It therefore follows that the (vaporous) centre—that is, the matter (in a vaporous condition) occupying the centre, must have been under the same pressure from the gravitation of the

superincumbent matter as that to which in the same situation it is now subjected. This consideration at once much increases the difficulty of imagining many of those substances, at present only known to us as solids, in a fluid or vaporous state; because we are called on to suppose them able to assume and retain that condition under enormous pressure. It seems much more reasonable to suppose that at the very elevated temperature of the hypothesis the conditions would be . . . the centre of the earth composed of matter in the liquid (fluid) state; exterior to or upon this, a crust of solid matter: then a stratum of dense vapor, becoming more gaseous and attenuated as the distance from the centre increased. On this supposition, as the cooling process gradually advanced, chemical combination and reaction of the materials upon each other would take place within, upon, and above the crust, and, also, the potent agency of volcanic action would be at work from the first in supplying and modifying the constituents, and in fashioning the form of the crust for the ulterior purpose it was intended to serve. We think that a careful consideration of the evidence now afforded by geology, together with the teaching of chemical and physical (meteorological) science, will be found to substantiate this supposition as to the primary condition of the earth. If then we assume that the earth at some former period was in a physical condition substantially such as we have just described, there can be no difficulty in supposing that some masses of aggregated matter, *i. e.*, planetary or cometary bodies, may be at the present time in a similar condition; indeed, it at once suggests itself as a probability that some of those very numerous bodies, of which astronomical observation has

made known to us the existence, are now in such a primary or igneous condition.* Keeping this probability in mind, let us now examine the appearances presented to a terrestrial observer by a comet.

Herschel's Outlines of Astronomy.

(556) "Comets consist for the most part of a large, and more or less splendid, but ill-defined, nebulous mass of light called the head, which is usually much brighter towards its centre, and offers the appearance of a vivid nucleus, like a star or planet. From the head and in a direction *opposite to that in which the sun is situated* from the comet appear to diverge two streams of light, which grow broader and more diffused at a distance from the head, and which most commonly close in and unite at a little distance behind it, but sometimes continue distinct for a great part of their course; producing an effect like that of the trains left by some bright meteors, or like the diverging fire of a sky-rocket (only without sparkle or perceptible motion). This is the tail."

(557) "The tail is, however, by no means an invariable appendage of comets, many of the brightest have been observed to have short and feeble tails, and a few great comets have been entirely without them. Those of 1585, and 1763, offered no vestige of a tail; and Cassini describes the comets of 1665, and 1682, as being as round and as well defined as Jupiter. On the other hand instances are not wanting of comets furnished with many

* If the condition of all the planetary bodies known to us was found to be, so far as we could observe, precisely similar and uniform, the probability would be against the above supposition; but since, on the contrary, observation has made certainly known to us that the present conditions of the various planets are dissimilar and differ very considerably, the probability is strongly in favor of the supposition.

tails or streams of diverging light. That of 1744 had no less than six, spread out like an immense fan, extending to a distance of nearly 30° in length. The small comet of 1823 had two, making an angle of about 160°, the brighter turned as usual from the sun, the fainter towards it, or nearly so. The tails of comets, too, are often somewhat curved, bending, in general, towards the region which the comet has left, as if moving somewhat more slowly, or as if resisted in their course."

Lardner's Astronomy.

(3092) "The comet (Halley's comet 1835) first became visible as a small round nebula, without a tail, and having a bright point more intensely luminous than the rest eccentrically placed within it."

Also, see Illustrations, Plates 9, 10, 11, 12, 13.

(2) *Explanation of the Phenomena.*

The description given by others of the general appearance of comets, is in agreement with the foregoing, viz., as consisting of a nebulous mass, more or less luminous, at or near the centre of which is the nucleus having the appearance of concentration or solidity, and which is also more vividly luminous; the tail or train of luminous matter which forms part of the usual cometary appearance, varying greatly in form and extent.

Now if we suppose a planetary mass of matter in a condition similar to that of the earth in its primary state, moving at a very considerable distance from the earth, the appearance it might be expected to present, leaving out of consideration for the moment the luminous train or tail, would be precisely that described as belonging to the comet; viz., the spherical mass of matter in a liquid (molten or fluid) state occupying the central part of the

body, covered by the solid crust in an intensely heated condition and surrounded by the vaporous and gaseous envelope would give the appearance of the nucleus and the coma. The supposition that the peculiar general appearance of cometary bodies is correctly accounted for in this manner is strengthened by astronomical observation which teaches us that all comets do not present this peculiar appearance but, are sometimes more similar and sometimes more dissimilar to ordinary planets. Thus "Cassini describes the comets of 1665 and 1682 as being as round and well defined as Jupiter; "the comets of 1585 and 1763 offered no vestige of a tail;" and "the smaller comets, such as are visible only in telescopes or with difficulty by the naked eye, and which are by far the most numerous, offer very frequently no appearance of a tail, and appear only as round or somewhat oval vaporous masses, more dense towards the centre, where, however, they appear to have no distinct nucleus, or anything which seems entitled to be considered as a solid body." (Herschel's Outlines.)

(3) *Natural division of comets into two classes.*

From the explanation which has been now given as to the orbital paths of comets, it follows that the observed comets would divide themselves into two classes,* viz.,

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*A third class would be those comets (if we suppose there are any) which belong entirely to some other system, and become occasionally visible from the earth; there is a probability that those comets of long period which have their orbital plane vertical or nearly vertical to the ecliptic, will be found to belong to this third class; and still more so where the motion is in the reverse direction to that of the planets belonging to the solar system. Again, the planetary comets might be divided into terrestrial and planetary comets; the first group containing all the comets of which the earth is the secondary centre of gravitation, and the second, all those having one of the other planets, to wit: Venus, Mars, Jupiter, Saturn, as the secondary centre.

sidereal (and solar) and planetary (and solar) comets; the former only partially, and the latter wholly belonging to the solar system. The former would evidently have orbital distances from the sun of great magnitude compared to the latter; and, in cases where the periodical return is observable, the periods of those belonging to the first class would be proportionately greater than those of the second. In comparing this reference with the record of actual observation, we find: "Here also we may notice a very curious remark of Mr. Hind (Ast. Nach. No. 724) respecting periodic comets, viz., that so far as at present known, they divide themselves for the most part into two families, the one having periods of about 75 years, corresponding to a mean distance about that of Uranus; the other corresponding more nearly with those of the asteroids, and with a mean distance between those small planets and Jupiter. The former group consists of four members; Halley's comet revolving in 76 years, one discovered by Oblers in 74, De Vico's 4th comet in 73, and Brorsen's 3rd in 75, respectively. Examples of the latter group are to be seen in the tables at the end of this volume." (*Herschel's Outlines.*) "We may add, too, a marked tendency in the major axis of periodical comets to ground themselves about a certain determinate direction in space, that is to say, a line pointing to the sphere of the fixed stars northward to 70° long. and 30° N. lat. or nearly towards the star λ Persei (in the Milky Way), and in the southern to a point (also in the Milky Way) diametrically opposite." (Ast. Nach. No. 853.)

(4) *The prevalent Theory of Cometary Orbits, and the facts of Astronomy.*

Persons who, it may be, are only slightly acquainted with astronomy, in a scientific sense, are likely to somewhat misunderstand the nature of the connection between the prevalent astronomical theory as to the cometary revolutions, and the astronomically observed facts belonging to the same subject. They are informed, or may so understand the matter, that the orbit of a comet having been calculated according to a theory affirming its path be in an ellipse of extreme eccentricity, and the p return of the comet having been found to agree or very nearly so with a prediction based on the result of that calculation, that such argument constitutes a strong probability as to the correctness of the theory; and since, in a number of instances, the predicted return of the comets, of which the orbits have been so calculated, has been verified by the actual return in agreement with the prediction, that the theory is demonstrated by the observed facts, and therefore it is safe to conclude that the eccentric theory of the cometary orbit is established. Such a conclusion is indeed very far from safe. It is true that certain computations based upon the theory are shown to bring out results which are in agreement with certain observed facts, but the nature of the case, which is of a compound character, makes it necessary to examine very carefully whether all the elements of the computation are in agreement with all the elements of the case, or, in other words, with all the known circumstances belonging to the fact, because, computations in which the elements vary greatly, comparing those of the one respectively with those of the other, may bring out

the same general result, and in this particular case the inference is that, as the result of the computation agrees with a certain fact (of observation), therefore all the elements of the computation are necessarily true, or according to fact, also. To point the objection to such an inference, we will observe that any compound arithmetical number may be arrived at, as a result, by combinations, in two or more computations, of elements which respectively (or taken separately) may differ considerably in the one computation from those in the other; for example, take the number 72, which results from 3 × 6 × 4, and also from 3 × 8 × 3, in one of which the 6 and the 4 differ respectively from the 8 and the 3 in the other: and, that the reader may correctly appreciate the merits of the case, we will suppose that the question is not as to whether the result is, or will be 72, because *that* is known beforehand, but as to the particular elements by which the result is produced. With respect, therefore, to the cometary predictions, they seem to amount to, but little more than this; a comet having been visible at a certain date and its appearance noted, and a definite number of years thereafter a comet, closely resembling the first, and apparently the same, having appeared; and again after the same definite number of years, the comet having reappeared; a strong probability suggests itself that the reappearances will be periodic at such intervals, and the next appearance or return of the comet is predicted accordingly. It appears that certain computations based upon a particular theory (the eccentric orbit theory) have been made to harmonize with the intervals of absence and re-appearance of the comets, but there is no sufficient evidence at present, so far as we are aware, of

a relation between the computations and the actual periods of the comets of such a kind as to justify the inference that the theory is supported, or in any way strengthened, by the return of certain comets at definite times, predicted in the manner just stated. Figures 7 and 8 will serve to illustrate the practical application of this argument.

(3) *Biela's Comet.*

Fig. 7, Pl. 5, is taken from *Arago's scientific notices of comets*, and shows the theoretical orbit of Biela's comet, with the supposed relative position of the orbital path of the earth. This comet was seen in 1826, 1832, and 1846; and it is also supposed to have been seen in 1772 and 1805, etc. Its orbit, according to Biela, is a very eccentric ellipse described about the sun in 2410 days, or about 6⅔ years.

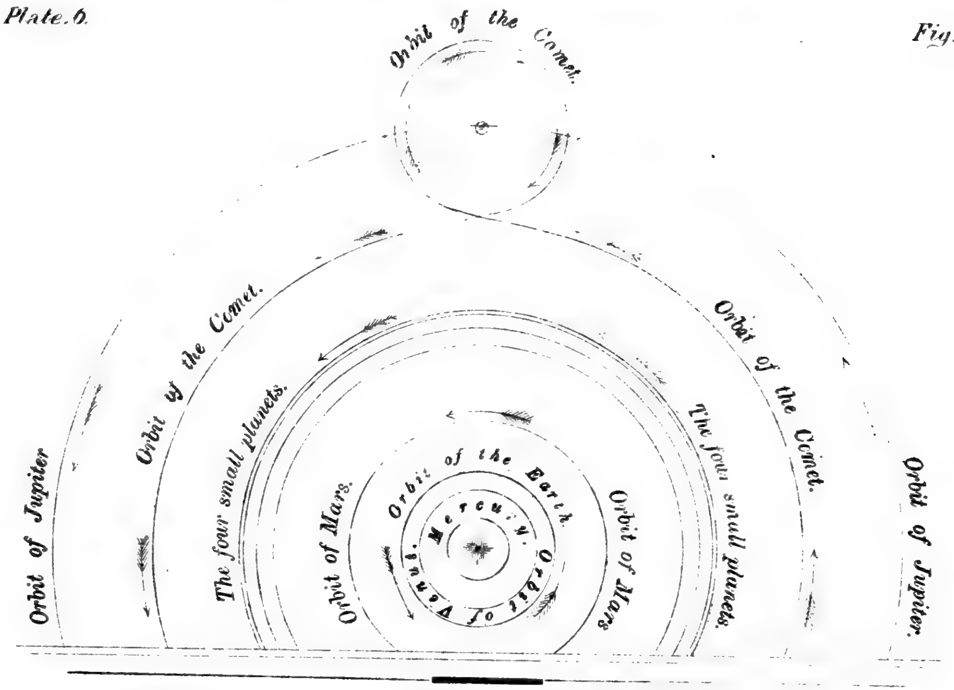
The following quotation from *Lardner's Astronomy* is noteworthy as indirectly illustrating the preceding argument and the succeeding application thereof:

"3024. *Corrected Estimate of the Mass of Mercury,*—The masses of comets in general are, as will be explained, incomparably smaller than those of the smallest of the planets; so much so, indeed, as to bear no appreciable ratio to them. A consequence of this is, that while the effects of their attraction upon the planets are altogether insensible, the disturbing effects of the masses of the planets upon them are considerable. These disturbances, being proportional to the disturbing masses, may then be used as measures of the latter, just as the movement of the pith-ball in the balance of torsion supplies a measure of the physical forces to which that instrument is applied.

Encke's comet near its perihelion passes near the orbit of Mercury, and when that planet at the epoch of its perihelion happens to be near the same point, a considerable and measurable disturbance is

Plate. 6.

Fig. 8.



The orbit of Biela's comet; assuming it to be a Jovian and Solar comet. Period, 900 days.

manifested in the comet's motion, which being observed supplies a measure of the planet's mass.

This combination of the motions of the planet and comet took place under very favourable circumstances, on the occasion of the perihelion passage of the comet in 1838, the result of which, according to the calculations of Professor Encke, was the discovery of an error of large amount in the previous estimates of the mass of the planet. After making every allowance for other planetary attractions, and for the effects of the resisting medium, the existence of which it appears necessary to admit, it was inferred that the mass assigned to Mercury by Laplace was too great in the proportion of 12 to 7

This question is still under examination, and every succeeding perihelion passage of the comet will increase the data by which its more exact solution may be accomplished.

3025. *Biela's Comet.*—On February 28th, 1826, M. Biela, an Austrian officer, observed in Bohemia a comet, which was seen at Marseilles at about the same time by M. Gambart. The path which it pursued, was observed to be similar to that of comets which had appeared in 1772 and 1806. Finally, it was found that this body moved round the sun in an oval orbit, and that the time of its revolution was about 6 years and 8 months. It has since returned at its predicted times, and has been adopted as a member of our system, under the name of Biela's comet.

Biela's comet moves in an orbit whose plane is inclined at a small angle to those of the planets. It is but slightly oval, the length being to the breadth in the proportion of about four to three. When nearest to the sun, its distance is a little less than that of the earth; and when most remote from the sun, its distance somewhat exceeds that of Jupiter.* Thus it ranges through the solar system, between the orbits of Jupiter and the Earth.

This comet had been observed in 1772 and in 1806; but in the elliptic form of its orbit, and consequently its periodicity was not discovered. Its return to perihelion was predicted and observed in 1832, in 1846, and in 1852; but that which took place in 1838 escaped observation, owing to its unfavourable position and extreme faintness."

* The distance of Jupiter to that of the earth is, in round numbers, about 5 : 1, therefore the above orbit should be . . the length to the breadth in the proportion of about 6 : 3½, instead of 4 : 3.

Fig. 8, Pl. 6, exhibits a theoretical orbit of the same comet which we propose to substitute for that of Biela, on the ground that the orbit now proposed affords a reasonable explanation of the observed facts, and which the former (Biela's) does not. The object of contrasting these two figures is, in the first place, to show that the situations in which the comet was actually seen at the various times of the observations, as well as the definite periods of its absence and of its return, *i.e.*, from the time when it becomes invisible until the time when it again becomes visible, can be explained by attributing to the comet an orbit essentially different from that of Biela. We divide the so-called period of the comet, 2410 days by three, and we consider the resulting number, 803⅓ days, to be (about) the actual period of the comet, that is to say, from the time of an observed appearance until the next. The orbit, as shown by the figure, is compound, belonging in part to the planet Jupiter. It is evident that if we assume these relative periods for the comet and the earth, that the earth will make two complete revolutions and be in advance of the comet by about 73⅓ days in the 1st period; in the 2nd period, the earth will make two complete revolutions and gain another 73⅓ days, making together 146⅔ days, and at the end of the third period, the earth will have made six annual revolutions and have gained 220 days. At this time the comet again becomes visible from the earth in a situation nearly the same relatively to the earth as when it was observed 2410 days previously. During this longer term the comet might be twice visible from the earth; but the frequency of the comet's re-appearance would be, in the first place, dependant upon the relative situation in its orbit of the planet Jupiter, because if the comet was in its planetary

orbit (revolving around Jupiter) at the time that the earth passed by, the comet would not be visible from the earth until overtaken again in the next revolution; and, in the second place, it should be observed that, when the comet becomes visible in November or February, the earth is situated (vertically) much below the plane of the ecliptic, not very far from its point of maximum depression; now, if the comet was seen at that time of the year when the earth is near its point of maximum elevation and therefore much above the plane of the ecliptic, the difference in the apparent relative situation might alone prevent the recognition of the comet. *

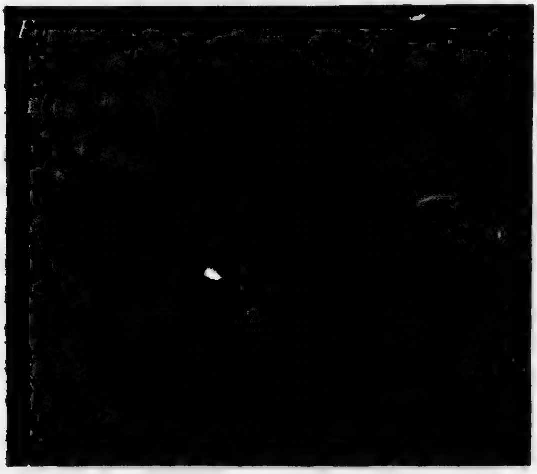
According to this explanation the comet's true period considered as its third return to the same sidereal (or fixed) place in the heavens (*i.e.*, to a place situated at the same point of the solar compass) will be somewhat (about 145 days) more than 7 years, because when the comet again becomes visible the earth requires 145 days to reach its former situation, which would complete the 7 years, and the comet moves with only about one-half the angular velocity of the earth. And, also, since the period of Jupiter is nearly 12 years, that planet would make rather more than half a revolution during the 7 years, so that a great number of these septennial re-appearances might occur before the planet's situation in the zodiac would cause the comet to leave the solar orbit at that particular time of the year when its return was expected, and so prevent its being seen from the earth at the time of its usual re-appearance.

* And moreover the comet must certainly have its periods of vertical elevation and depression which, instead of coinciding with those of the earth, may be in opposition thereto, and hence considerably increase the apparent difference in the relative situation.)

(4) *Notices from the Record of various comets.*

Halley's Comet.

Fig. 9* represents the supposed orbit of Halley's comet, and is a fair illustration of the elliptical orbit of extreme eccentricity, which is now attributed to cometary bodies. We observe that the comet, having nearly reached its perihelion, makes about one-third of a revolution around



the sun in moving from *A* to *B*, but having arrived at *B*, and still being comparatively very near to the sun, it no longer obeys the restraining power of the sun's gravitating influence, but recedes in an almost direct line to a great distance, then, describing a slight curve towards the major axis of the ellipse, it gradually approaches its (supposed) aphelion *C*. Notwithstanding that the comet when at *B*, comparatively close to the sun, was unaffected

* From Dick's "Sidereal Heavens."

by the enormous gravitating force to which it must have been at that place subjected, now, when near *C* at the very great distance *S. C*, it becomes suddenly and sensitively attentive to the comparatively very feeble influence of the sun and describes the short curve shown at *C* (the supposed aphelion); but, here again, it appears quite evident that if the velocity of the comet at this place is so small and the sun's influence sufficiently great to cause the comet to make the comparatively sudden curve shown at *C*, the further result will be the motion of the comet in an almost direct line towards the sun as shown in Fig. 10.

The following are *Mr. Dick's* observations having reference to the figure: "The orbit of Halley's comet is four times longer than it is broad, and the orbits of those comets whose periodical revolution exceeds a hundred or a thousand years must be still more elongated and eccentric. The following figure (Fig. 9) represents the orbit of Halley's comet nearly in its exact proportions—*E. C.* represents the length of the ellipse in which it performs its revolution; *E. D.* the orbit of the earth somewhat longer than it ought to be in proportion to the comet's orbit; *S.* the sun in one of the foci of the ellipse; *Sat.* the proportional distance of the planet Saturn from the sun; and *U*, the proportional distance of Uranus. The orbit of this comet extends to nearly double the distance of Uranus, and considerably beyond the orbit of the lately discovered planet Neptune."

The following extract from *Dr. Lardner's Treatise on Astronomy* will serve to illustrate more especially the subject of the 'planetary comets' by which we mean those which have a compound solar-and-planetary orbit such as we have attributed to the comet known as Biela's.

(3036) "Lexell's comet.—The history of Astronomy has recorded one singular example of a comet which appeared in the system, made two revolutions round the sun in an elliptic orbit, and then disappeared, never having been seen either before or since

This comet was discovered by Messier, in June, 1770, in the constellation of Sagittarius between the head and the northern extremity of the bow, and was observed during that month. It disappeared in July, being lost in the sun's rays. After passing through its perihelion, it reappeared about the 4th of August, and continued to be observed until the first days of October, when it finally disappeared. All the attempts of the astronomers of that day failed to deduce the path of this comet from the observations, until six years later, in 1776, Lexell showed that the observations were explained, not as had been assumed previously, by a parabolic path, but by an ellipse, and one, moreover, without any example at that epoch, which indicated the short period of 5½ years.

It was immediately objected to such a solution that its admission would involve the consequence that the comet, with a period so short, and a magnitude and splendour such as it exhibited in 1770, must have been frequently seen on former returns to perihelion; whereas no record of any such appearance was found.

To this Lexell replied, by showing that the elements of its orbit, derived from the observations made in 1770, were such, that at its previous aphelion, in 1767, the comet must have passed within a distance of the planet Jupiter fifty-eight times less than its distance from the sun; and that consequently it must then have sustained an attraction from the great mass of that planet more than

three times more energetic than that of the sun; that consequently it was thrown out of the orbit in which it actually moved in 1770; that its orbit previously to 1767 was, according to all probability, a parabola; and, in fine, that consequently moving in an elliptic orbit from 1767 to 1770, and having the periodicity consequent on such motion, it nevertheless moved only for the first time in its new orbit, and had never come within the sphere of the Sun's attraction before this epoch. Lexell further stated, that since the comet passed through its aphelion which nearly intersected Jupiter's orbit at intervals of 5½ years, and it encountered the planet near that point in 1767, the period of the planet being somewhat above 11 years, the planet after a single revolution and the comet after two revolutions must necessarily again encounter each other in 1779; and, that since the orbit was such that the comet must in 1779 pass at a distance from Jupiter 500 times less than its distance from the sun, it must suffer from that planet an action 250 times greater than the sun's attraction, and that therefore it would in all probability be again thrown into a parabolic or hyperbolic path; and, if so, that it would depart for ever from our system to visit other spheres of attraction. Lexell, therefore, anticipated the final disappearance of the comet, which actually took place.

In the interval between 1770 and 1779, the comet returned once to perihelion; but its position was such that it was above the horizon only during the day, and could not in the actual state of science be observed."

(3037) "At this epoch analytical science had not yet supplied a definite solution of the problem of cometary disturbances. At a later period the question was assumed

"by Laplace, who in his celebrated work, the *Mécanique Céleste*, gave the general solution of the following problem: 'The actual orbit of a comet being given, what was its orbit before, and what will be its orbit after being submitted to any given disturbing action of a planet near which it passes?'"

(3038.) "Applying this to the particular case of Lexell's comet, and assuming as data the observations recorded in 1770, Laplace showed that before sustaining the disturbing action of Jupiter in 1767, the comet must have moved in an ellipse, of which the semi-axis major was 13·293, and consequently that its period, instead of being 5½ years must have been 48½ years; and that the eccentricity of the orbit was such, that its perihelion distance would be little less than the mean distance of Jupiter, and that consequently it could never have been visible. It followed also, that, after suffering the disturbing action of Jupiter in 1779, the comet passed into an elliptic orbit, whose semi-axis major was 7·3; that its period was consequently 29 years, and its eccentricity such that its perihelion distance was more than twice the distance of Mars, and that in such an orbit, it could not become visible."

(3039.) "This investigation has recently been revised by M. Le Verrier (See Mem. Acad. des Sciences, 1847, 1848,) who has shown that the observations of 1770 were not sufficiently definite and accurate to justify conclusions so absolute. He has shown that the orbit of 1770 is subject to an uncertainty, compassed between certain definite limits; that tracing the consequences of this to the positions of the comet in 1767 and 1779, these positions are subject to still wider limits of uncertainty. Thus he

"shows that compatible with the observations of 1770, the comet might in 1779 pass either considerably outside or considerable inside Jupiter's orbit, or might, as it was supposed to have done, have passed actually within the orbit of his Satellites. He deduces in fine, the following general conclusions:

1. That if the comet had passed within the orbits of the Satellites, it must have fallen down upon the planet and coalesced with it; an incident which he thinks improbable, though not absolutely impossible.

2. The action of Jupiter may have thrown the comet into a parabolic or hyperbolic orbit, in which case it must have departed from our system altogether, never to return except by the consequence of some disturbance produced in another sphere of attraction.

3. It may have been thrown into an elliptic orbit, having a great axis and a long period, and so placed and formed that the comet could never become visible; a supposition within which comes the solution of Laplace.

4. It may have had merely its elliptic elements more or less modified by the action of the planet, without losing its character of short periodicity; a result which M. le Verrier thinks the most probable, and which would render it possible that this comet may still be identified with some one of the many comets of short period which the activity and sagacity of observers are every year discovering."

TABLE III.*

SYNOPSIS OF THE MOTION OF THE ELLIPTIC COMETS WHICH REVOLVE WITHIN THE ORBIT OF SATURN.

	Designation.		Mean distance Earth=1	Period Years.	Inclination. ° ′ ″	Time of Perihelion passage.	Direction of motion
1	Encke.	....	2.2148	3.296	13 7 24	March 14, 1852. 18h. 58m	D
2	Biela.	....	3.5245	6.617	12 34 53	Febry. 10, 1846. 23 42	D
3	Faye.	....	3.8118	7.141	11 22 31	Oct. 17, 1843.... 3 38	D
4	De Vico.	....	3.1028	5.469	2 54 45	Sept. 2, 1844.....11 36	D
5	Brorsen.	....	3.1465	5.581	30 57 51	Febry. 25, 1846.. 7 57	D
6	D. Arrest.	....	3.4618	6.441	13 56 12	July 8, 1851.....16 48	D
7	Claussen.	1743	3.0913	5.435	1 53 43	Jany. 8, 1743.... 4 39	D
8	Burckhardt.	1766	2.9337	5.025	8 1 45	April 26, 1766....23 44	D
9	Lexell.	1770	3.1560	5.607	1 34 28	Aug. 13, 1770....12 56	D
10	Blainplan.	1819	2.8490	4.809	9 1 16	Nov. 20, 1819.... 6 3	D
11	Pons.	1819	3.1602	5.618	10 42 48	July 18, 1819....21 46	D
12	Pigott.	1783	4.6496	10.025	17 48 00	Nov. 19, 1783....13 30	D
13	Peters.	1846	6.3206	15.990	13 2 14	June 1, 1846..... 2 40	D

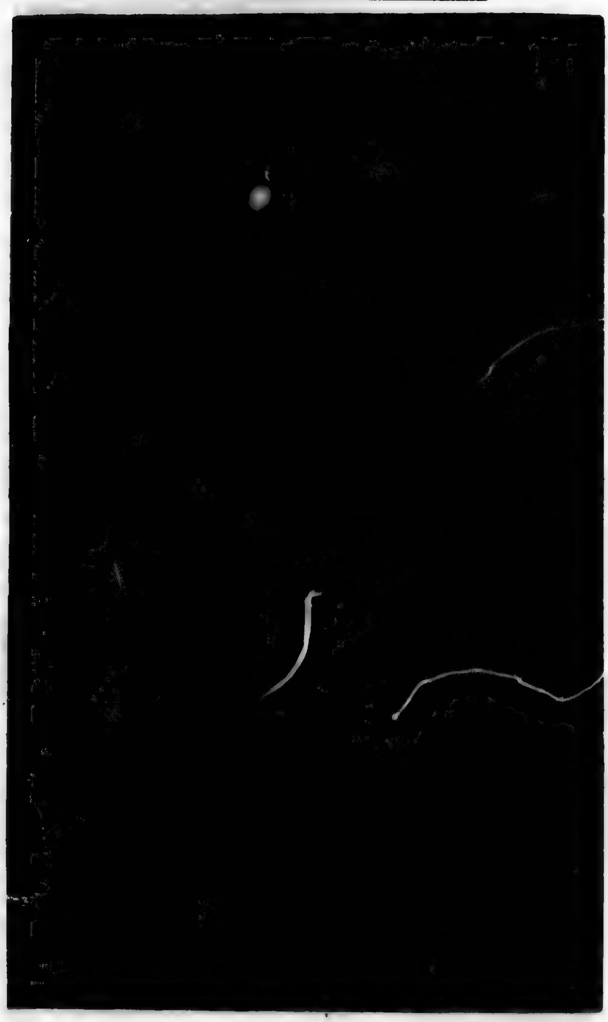
3048. "*Diagram of the orbits.* In Fig. 817, the orbits of these thirteen comets, brought to a common plane, are represented roughly but in their proper proportions and relative positions, so as to exhibit to the eye their several ellipticities, and the relative directions of their axes. All those bodies, without one exception, revolve in the common direction of the planets."

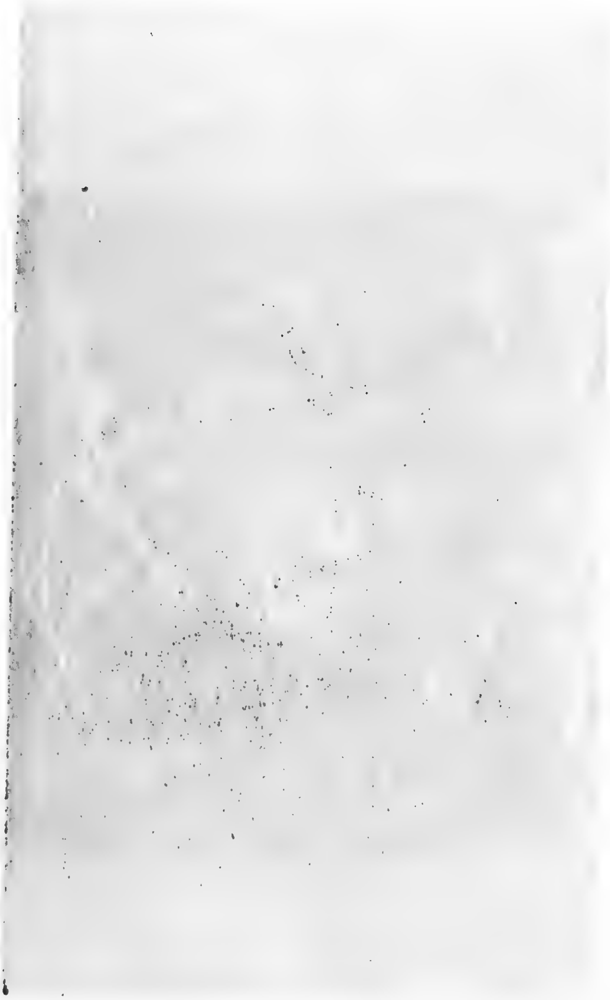
3049. "It is not alone, however, in the direction of their motions that the orbits of these bodies have an analogy to those of the planets. Their inclinations, with one exception, are within the limits of those of the planets. Their eccentricities, though incomparably greater than those of the planets, are, as will presently appear, incomparably less than those of all other comets yet discovered. Their mean distances and periods (with the exception of the last two in the table), are within the limits of those of the planetoids."

* We give here only a part of the table; omitting the elements of the elliptical orbits, calculated on the basis of the cometary theory. The complete tables may be found in *Lardner's Astronomy*, from which they are quoted.

From Lardner's Astronomy.

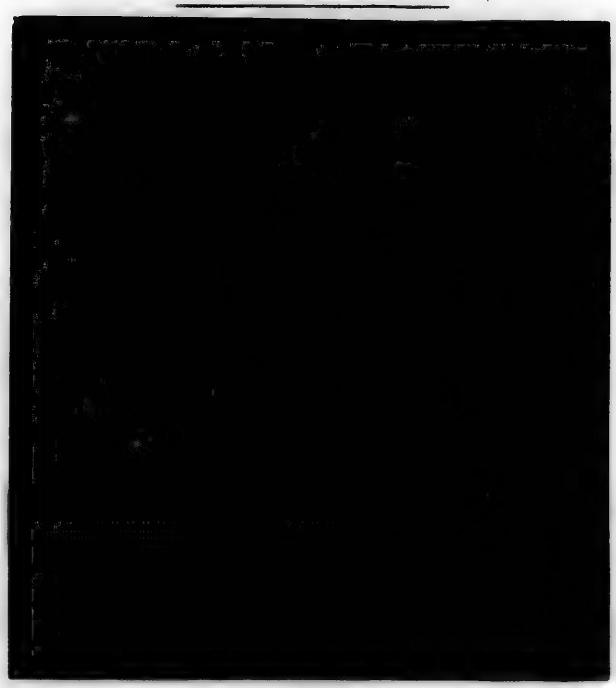
PLATE 7. FIG. 817.





From Lardner's Astronomy.

PLATE 8. FIG 882.



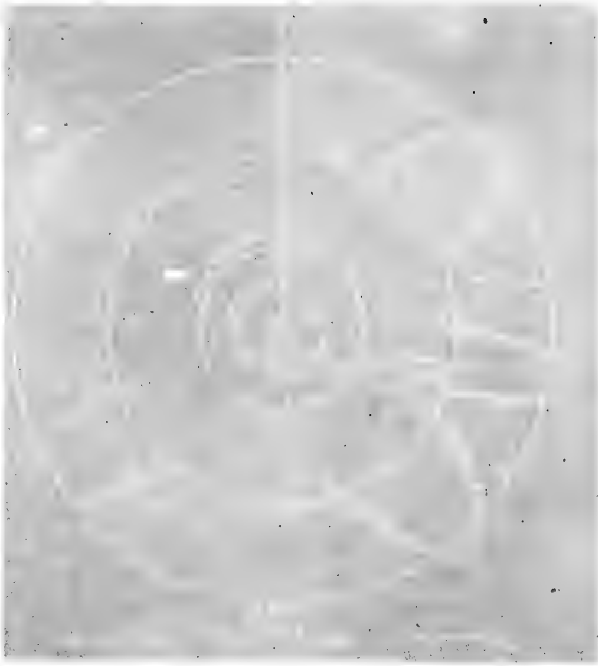


TABLE V.*

SYNOPSIS OF THE MOTION OF THE ELLIPTIC COMETS WHOSE MEAN DISTANCES ARE NEARLY EQUAL TO THAT OF URANUS.

Designation.		Mean distance Earth=1	Period Years.	Inclination. ° ′ ″	Time of perihelion passage.	h.	m.	Direction of motion.
Halley.	....	17.9875	76.680	17 45 5	Nov. 15, 1835...	22	41	R
Pons.	1812	17.0955	70.068	73 57 3	Sept. 15, 1812...	7	41	D
Olbers.	1815	17.6338	74.050	44 29 55	April 25, 1815...	25	58	D
De Vico.	1846	14.5386	73.250	84 57 13	March 5, 1846...	14	1	D
Brorsen.	1847	17.7795	74.970	19 8 25	Sept. 9, 1847....	13	11	D
Westphal.	1852	16.6200.	67.770	40 58 32	Oct. 12, 1852....	15	6	D

Diagram of the orbits.

"In Fig. 820, is presented a plan of their orbits brought upon a common plane, and drawn according to the scale indicated. This figure shows, in a manner sufficiently exact for the purposes of illustration, the relative magnitudes and forms of the six orbits, as well as the directions of their several axes with relation to that of the first point of Aries."

* See Note to page 42.

TABLE VI.*

SYNOPSIS OF THE MOTIONS OF THE ELLIPTIC COMETS WHOSE MEAN DISTANCES EXCEED THE LIMITS OF THE SOLAR SYSTEM.

Designation.		Mean Distance Earth =1.	Neptune =1	Period in Years.	Inclination. °	′	″	Time of perihelion passage.	h.	m.	Direction of motion.
1	1680	427.6487	† 4.2547	8813	60	40	16	Dec. 17, 1680.....	23	55	D
2	1683	33.0310	1.1010	190	83	47	46	July 12, 1683.....	17	35	R
3	1763	217.4074	7.2469	3205	72	34	10	Nov. 1, 1763.....	21	4	D
4	1769	163.4575	5.4458	2089	40	45	50	Oct. 7, 1769......	15	3	D
5	1780	1787.9200	59.5978	75838	54	23	12	Sept. 30, 1780....	22	28	R
6	1793	56.2000	1.9000	421	51	31	10	Nov. 28, 1793....	5	6	D
7	1807	143.8562	4.7952	1725	63	10	28	Sept. 18, 1807....	17	53	D
8	1811	211.0225	7.0340	3065	73	2	21	Sept. 12, 1811....	6	20	R
9	1811	91.5088	3.0503	875	31	17	11	Nov. 10, 1811....	23	56	D
10	1822	309.5000	10.3200	5444	52	39	10	Oct. 23, 1822.....	18	28	R
11	1825	267.9440	8.9314	4386	33	32	39	Dec. 10, 1825,....	16	31	R
12	1827	189.6187	6.3206	2611	54	4	42	Sept. 11, 1827....	16	47	R
13	1830	1536.0000	51.2000	60200	21	16	5	April 9, 1830.....	7	15	D
14	1840	577.1099	19.2370	13864	59	13	20	March 12, 1840...	23	56	R
15	1840	49.1100	1.6370	344	57	57	23	Nov. 13, 1840....	15	37	D
16	1843	56.0000	18.6000	376	35	41	9	Febry. 27, 1843..	9	47	R
17	1844	2138.0000	71.2600	100000	48	36	1	Oct. 17, 1844.....	8	15	R
18	1845	39.7600	1.3200	251	48	41	58	June 5, 1845.....	16	10	R
19	1846	194.8000	64 9000	2719	47	26	6	Jan. 22, 1846.....	2	15	D
20	1846	54.4192	1.8139	401	29	18	47	June 5, 1846......	12	35	R
21	1849	164.2000	5.4733	8375	66	59	2	June 8, 1839.....	4	10	D

† There is a want of strict agreement between this column and that of Earth = 1. For instance, in No. 2...the distance of Earth = 1 : distance, of Neptune = 1 (nearly) : : 33 : 1. In the average of the other numbers it is, more nearly, : : 31 : 1.

(3072.) "The distance to which the comet of 1680 recedes in its aphelion is 28½ times greater than that of Neptune. The apparent diameter of the sun seen from that distance would be 2″, and the intensity of its light and heat would be 730,000 times less than at the Earth, while their intensity at the perihelion distance would be 26,000 times greater, so that the light and heat received by the comet in its aphelion would be 26,000 × 730,000, = 18,980 million times less than in perihelion.

The greatest aphelion distances in the table are those of Nos. 5, 13, and 17, the comets of 1780, 1830 and 1844, amounting to from 100 to 140 times the distance of Neptune; the eccentricities differing from unity by less than $\frac{1}{1000}$. These orbits, though strictly the results of calculation, must be regarded as subject to considerable uncertainty."

* See Note to page 42.

"3073. *Plan of the form and relative magnitude of the orbits.*—To convey an idea of the form of the orbits of the comets of this group, and of the proportion which their magnitude bears to the dimensions of the solar system, we have drawn, in Fig. 821, an Ellipse, which may be considered as representing the form of the orbits of the comets Nos. 15, 6, 9, 12 and 1 of the Table VI.

If the Ellipse represent the orbit of the comet No. 15, the circle *a*, will represent on the same scale the orbit of Neptune.

If the Ellipse represent the orbit of the comet No. 6, the circle *b*, will represent the orbit of Neptune.

If the Ellipse represent the orbit of No. 9, the circle *c*, will represent the orbit of Neptune.

If the Ellipse represent the orbit of No. 12, the circle *d*, will represent the orbit of Neptune.

If the Ellipse represent the orbit of No. 1, the circle *e*, will represent the orbit of Neptune."

TABLE VII.*

SYNOPSIS OF THE MOTIONS OF THE HYPERBOLIC COMETS.

	Time of perihelion passage.	h.	m.	Perihelion distance Earth=1	Inclination. ° ′ ″	Direction of motion.
1	June 13, 1729.......	6	19	4.0435	77 5 10	D
2	April 19, 1771,......	5	16	0.9035	11 15 19	D
3	August 15, 1774......	10	5	1.4229	83 20 26	D
4	Dec. 5, 1818.........	0	56	0.3550	63 0 24	R
5	Sept. 29, 1824........	1	24	1.0500	54 36 59	D
6	Jan. 4, 1840..........	10	23	0.6184	53 5 32	D
7	May 6, 1843.........	1	30	0.6163	52 44 46	D

* See Note to page 42.

TABLE VIII.

OF OTHER OBSERVED COMETS.

	Time of Perihelion passage.	h. m.	Perihelion distance Earth=1.	Inclination °	′	″	Direction of motion.
1	B.C. 370, Winter........	0. 0	very small	30	0	0	R
2	136, April 29...........	0. 0	1. 01	20	0	3	R
3	63, July................	0. 0	0. 80	70	0	0	D
4	11, October 8	19.12	0. 58	10	0	0	R
5	A.D. 60, January 14.....	4.48	0. 445	40	30	0	R
6	141, March	2.24	0. 720	17	0	0	R
7	200, November 9.........	23.51	0. 372	44	0	0	D
8	539, October 20	14.51	0. 341	10	0	0	D
9	565, July 14............	11.51	0. 832	59	0	0	R
10	568, August 28..........	6.29	0. 889	4	0	0	D
11	5, April 7..............	6.43	0. 963	43	31	0	D
12	770, June 6.............	15.22	0. 603	59	31	0	R
13	837, February 28	23.51	0. 580	10 to 12	0	0	R
14	961, December 30........	3.50	0. 552	79	33	0	R
15	989, September 11.......	23.51	0. 568	17	0	0	R
16	1066, April 1...........	0. 0	0. 720	17	0	0	R
17	1092, February 15.......	0. 0	0. 928	28	55	0	D
18	1097, September 21......	21.27	0. 738	73	30	0	D
19	1231, January 30........	7.13	0. 948	6	5	0	D
20	1264, July 15...........	23.51	0. 430	30	25	0	D
21	1299, March 31..........	7.29	0. 318	68	57	0	R
22	1301, October 23........	23.51	0. 640	13	0	0	R
23	1337, June 22...........	19.12	0. 937	42	54	0	R
24	1351, November 2[illegible]......	23.51	1. 000	..	..	.	D
25	1362, March 11..........	4.51	0. 456	21	0	0	R
26	1366, October 13	0.00	0. 958	6	0	0	R
27	[illegible], October 14.......	6.14	0. 774	52	15	0	R
28	[illegible], November [illegible]......	4.34	0. 329	77	14	0	R
29	1457, [illegible].......	16.48	2. 103	20	20	0	D
30	[illegible], October 7........	9.50	0. 853	44	19	0	R
31	1472, February [illegible].......	5.13	0. 539	1	55	0	R
32	1490, December 24.......	11.17	0. 738	51	37	0	D
33	1506, September 3.......	15.53	0. 386	45	1	0	R
34	1532 October 19	22.18	0.5091	32	36	0	D
35	1533, June 4............	21.11	0.3269	28	14	0	D?
*36	1533, June 16...........	19.31	0.2028	35	49	0	R?
36	1556, April 22..........	0.34	0.5040	30	12	12	D
37	1558, August 10.........	12.25	0.5773	73	29	0	R
38	1577, October 26........	22.25	0.1775	75	9	42	R
39	1580, November 28.......	1[illegible].45	0.5955	64	52	0	D
40	1582, May 6.............	16 00	0.2257	61	28	0	R
41	1585, October 8	2.[illegible]5	1 0954	6	5	4	D
42	1590, February 8........	0.39	0.5677	29	29	44	..
43	1593, July 18...........	13.39	0.0891	87	58	0	..
44	1496, July 25...........	5. 9	0.5672	51	58	10	..
45	1618, August 17	3. 3	0 5130	21	28	0	D
46	1618, November 8	8.25	0.3896	37	11	31	D
47	1652, November 12	15.41	0.8475	79	28	0	D
48	1661, January 26........	21. 9	0 4427	33	0	55	D
49	1664, December 4........	11.53	1.0258	21	18	30	R
50	1665, April 24..........	5.16	0.1065	76	5	0	R
51	1668, February 24	18.46	0.2511	27	7	0	D?
*51	1668, February 28	19.12	0.0048	35	50	0	R?
52	1672, March 1...........	8.38	0 6974	83	22	10	D
53	1677, May 6.............	0.38	0.2806	79	3	15	R
54	1678, August 26.........	14. 4	1.2380	3	4	20	D
55	1684, June 8	10.17	0.9602	65	48	40	D
56	1686, September 16......	14.34	0.3250	31	21	40	D
57	1689, December 1........	14.56	0.0169	69	17	0	R
58	1695, November 9........	16.51	0.8435	22	0	0	D
59	1698, October 18........	16.58	0.0013	11	46	0	R
60	1699, January 13........	8.23	0 7940	69	20	0	R
61	1701, October 17........	9.51	0.5926	41	39	0	R
62	1702, March 13..........	14.33	0.6468	4	24	44	D
63	1706, January 30........	4.23	0.4258	55	14	10	D

TABLE VIII.—*Continued.*

	Time of Perihelion passage.	h. m.	Perihelion distance Earth=1.	Inclination ° ′ ″	Direction of Motion.
64	1718, January 14........	21.42	1 0254	31 8 6	R
65	1723, September 27......	15. 4	0 9988	50 0 18	R
66	1729, June 12............	17.51	4 0431	77 5 18	D
67	1737, January 30........	8.21	0 2228	18 20 45	D
68	1737, June 8............	7.39	0 8670	39 14 5	D
69	1739, June 17	10 00	0 6736	55 42 44	R
70	1742, February 8........	4.39	0 7657	66 59 14	R
71	1743, January 10........	20.20	0 8382	2 16 16	D
72	1743, September 20......	21.17	0 5216	45 48 21	R
73	1744, March 1...........	8.17	0 2221	47 8 36	D
74	1746, February 15.......	0. 0	0 95	6 0 0	D
75	1747, March 3	7.11	2 1985	79 6 20	R
76	1748, April 28...........	18.44	0 8404	85 28 22	R
77	1748, June 18	21.18	0 6254	67 3 28	D
78	1757, October 21........	7.55	0 3375	12 50 20	D
79	1758, June 11	3.18	0 2154	68 19 00	D
80	1759, November 27......	2.19	0 7985	78 59 22	D
81	1759, December 16......	21 4	0 9660	4 51 32	R
82	1762, May 23............	8. 2	1 0091	85 38 13	D
83	1764, February 12.......	13 42	0 5562	52 53 31	R
84	1766, February 17.	8.41	0 5033	40 50 20	R
85	1770, November 22.......	5.39	0 5282	31 25 55	R
86	1773, September 5.......	1. 34	1 1269	61 14 17	D
87	1779, January 4..........	2. 4	0 7132	32 30 57	D
88	1780, November 28......	20.21	0 5152	72 3 30	R
89	1781, July 7.............	4.32	0 7758	81 43 26	D
90	1781, November 29.....	12.32	0 9610	27 13 8	R
91	1784, January 21........	4 47	0 7079	51 9 12	R
92	1785, January 27........	7.49	1 1434	70 14 12	D
93	1785, April 8............	8.59	0 4273	87 31 54	R
94	1786, July 7	21.51	0 4101	50 54 28	D
95	1787, May 10............	19.49	0 3489	48 15 51	R
96	1788, November 10......	7.25	1 0630	12 27 40	R
97	1788, November 20......	7.16	0 7573	64 30 24	D
98	1790, January 15.......	5. 6	0 7581	31 54 15	R
99	1790, January 28........	7.36	1 0633	56 58 13	D
100	1790, May 21...........	5 47	0 7980	63 52 27	R
101	1792, January 13........	13.35	1 2930	39 46 55	R
102	1792, December 27	6. 5	0 9063	49 1 45	R
103	1793, November 4........	20.12	0 4034	60 21 00	R
104	1796, April 2............	19.48	1 5782	64 54 23	R
105	1797, July 9.............	2.31	0 5266	50 40 34	R
106	1798, April 4............	11.32	0 4848	43 52 16	D
107	1798, Dec. 31	13.17	0 7795	42 26 4	R
108	1799, September 7.......	5.39	0 8399	50 56 27	R
109	1799, December 25	21.31	0 6258	77 1 38	R
110	1801, August 8.....	13.33	0 2617	21 20 0	R
111	1802, September 9.......	21.23	1 0941	57 0 47	D
112	1804, February 13	15.31	1 0723	56 54 20	D
113	1806, December 28.......	22.21	1 0816	35 2 50	R
114	1808, May 12............	22.52	0 3899	45 43 7	R
115	1808, July 12............	5.16	0 6073	39 17 24	R
116	1810, October 5..........	19.45	0 9691	62 46 17	D
117	1813, March 4	12.38	0 6991	21 13 33	R
118	1813, May 19............	10. 8	1 2161	81 2 28	R
119	1816, March 1	8 18	0 0485	43 5 26	D
120	1818, February 25	23 1	1 1978	89 43 48	D
121	1818, December 4	22 26	0 8551	63 5 29	R
122	1819, June 27	17 11	0 3410	80 44 44	D
123	1821, March 21	12 53	0 0918	73 33 7	R
124	1822, May 5	14 33	0 5044	53 37 24	R
125	1822, July 16............	12 45	0 8367	38 12 39	R
126	1823, December 9	10 39	0 2265	76 11 57	R
127	1824, July 11	12 9	0 5912	54 34 19	R
128	1825, May 30............	13 9	0 8891	56 41 6	R
129	1825, August 18	17 4	0 8834	89 41 47	D
130	1826, April 21	23 4	2 0111	40 2 33	D
131	1826, April 29...........	0 56	0 1881	5 17 2	R
132	1826, October 8...........	22 51	0 8528	25 57 13	D

TABLE VIII.—*Continued.*

	Time of Perihelion passage.	h. m.	Perihelion distance Earth = 1.	Inclination ° ′ ″	Direction of Motion.
133	1826, November 18......	9 54	0 0269	89 22 10	R
134	1827, February 4.........	22 7	0 5065	77 35 33	R
135	1827, June 7....	20 9	0 8081	43 38 45	R
136	1830, December 27	15 51	0 1258	44 45 30	R
137	1832, September 25......	12 31	1 1836	43 18 3	R
138	1833, September 10......	4 28	0 4584	7 21 2	D
139	1834, April 2	15 5	0 5150	5 56 52	D
140	1835, March 27.........	13 50	2 0143	9 7 39	R
141	1840, April 2.........	12 54	0 7421	75 51 24	D
142	1842, December 15 ...	22 58	0 5044	73 34 4	R
143	1844, December 13	16 23	0 2513	45 36 31	D
144	1845, January 8	3 44	1 9052	46 50 30	D
145	1845, April 21	0 45	1 2547	56 23 36	D
146	1846, May 27............	21 57	1 2703	57 35 50	R
147	1846, October 29	17 56	0 8306	49 41 17	D
148	1847, March 30	6 28	0 0420	48 39 49	D
149	1847, June 4...........	16 34	2 1150	79 33 43	R
150	1847, August 9...........	8 17	1 4848	32 38 47	R
151	1847, August 9...........	10 37	1 7672	83 27 1	R
152	1847, November 14......	4 14	0 3500	72 10 51	R
153	1848, September 8	1 6	0 3199	84 24 50	R
154	1849, January 19.........	8 21	0 9597	85 2 54	D
155	1849, May 26..............	11 54	1 1593	67 9 39	D
156	1850, July 23.............	12 28	1 0815	68 12 8	D
157	1850, October 19	8 10	0 5655	40 5 37	D
158	1851, August 26..........	7 20	0 9814	37 48 57	D
159	1851, September 30......	10 12	0 1413	73 59 44	D
160	1852, April 19....	13 52	0 9050	48 52 54	R

We have given these last tables as affording a sort of classified record of the observed comets; and, inasmuch as they embody the results of certain more or less careful observations of those bodies, they have undoubtedly some value.

In respect to table VI. in particular, we must again remark the wildly improbable statements which the student of astronomical science is called upon to accept as fact. In the very extreme cases of this table, Dr. Lardner cautions the reader (art. 3072, quoted page 25) that the results must be regarded as subject to uncertainty, but this very caution may be taken to mean that in the less extreme cases there is no uncertainty; consequently the student is to understand that a comet may recede to a distance from the sun many times greater than the distance of the planet Neptune, and then be brought back again by the direct influence of solar gravitation after the lapse of some hundreds or, perhaps, even, of several thousands of years. The immediate corollary to these statements would be that 'gravitation' as it is known to us must be confined to the sun and the members of the solar system; because it is evident that, in receding to such a distance, the comet must enter other sidereal systems where, if the law of gravitation was in operation, it (the comet) would be subjected to the influence of the primary, as well as some of the secondary, centres of gravitation pertaining to those systems. It seems almost impossible to avoid the inference that it would become itself a planet, if not the satellite of a planet, belonging to some sidereal system or other; not to speak of the numerous perturbations to which, in such a prolonged and uncontrolled journey, it would be certainly subjected.

The following statement from *Dr. Lardner's Astronomy* together with the accompanying diagram illustrating it, will serve to define the present doctrine of cometary orbits and to show that we have not exaggerated the extravagant characters of the hypotheses by means of which

it has been sought to reconcile that doctrine with the laws of the material world.

"Subject to these limitations, however, a body may move round the sun in any orbit, at any distance, in any plane, and in any direction whatever. It may describe an ellipse of any eccentricity, from a perfect circle to the most elongated oval. This ellipse may be in any plane, from that of the ecliptic to one at right angles to it, and the body may move in such ellipse, either in the same direction as the earth or in the contrary direction. Or the body thus subject to solar attractions may move in a parabola with its point of perihelion at any distance whatever from the sun, either grazing its very surface or sweeping beyond the orbit of Neptune, or, in fine, it may sweep round the sun in an hyperbola entering and leaving the system in two divergent directions.

To render these explanations, which are of the greatest interest and importance in relation to the subject of comets, more clearly understood, we have represented in Fig. 816, the forms of a very eccentric ellipse $a\ b\ a'\ b'$, a parabola $a\ p\ p'$ and a hyperbola $a\ h\ h'$ having s as their common focus."

(8.) *The Comet's Luminous Train.*

The luminous character of the comet, and the peculiar appearance and characteristics of the luminous train or tail, have yet to be considered. Illustrations of these appearances will be found in plates 8, 9, 10, 11 and 12.

In the general description of a comet already given, the most usual appearance of the tail is defined in our quotation (page 11) from art. 556, of *Herschel's Outlines*, which art. continues thus · "This magnificent appendage attains occasionally an immense length. Aristotle relates of the tail of the comet of 371 B. C., that it occupied a third of the hemisphere, or 60°; that of A. D. 1618 is stated to have been attended by a train no less than 104° in length. The comet of 1680, the most celebrated of modern times, and on many accounts the most remarkable of all, with a head not exceeding in brightness a star of the second magnitude, covered with its tail an extent of more than 70° of the heavens, or, as some accounts state, 90°; that of the comet of 1769 extended 97°, and that of the last great comet [1843] was estimated at about 65° when longest. The figure (plate 11) is a representation of the comet of 1819—by no means one of the most considerable, but which was, however, very conspicuous to the naked eye." In some instances there are several streams of light diverging from the head as in that of the comet of 1744,* which "had no less than six, spread out like an immense fan, extending to a distance of nearly 30° in length." And in some cases (very frequently) the comet is, as already stated, without any luminous train or tail." † A circum-

*See Plate 13.

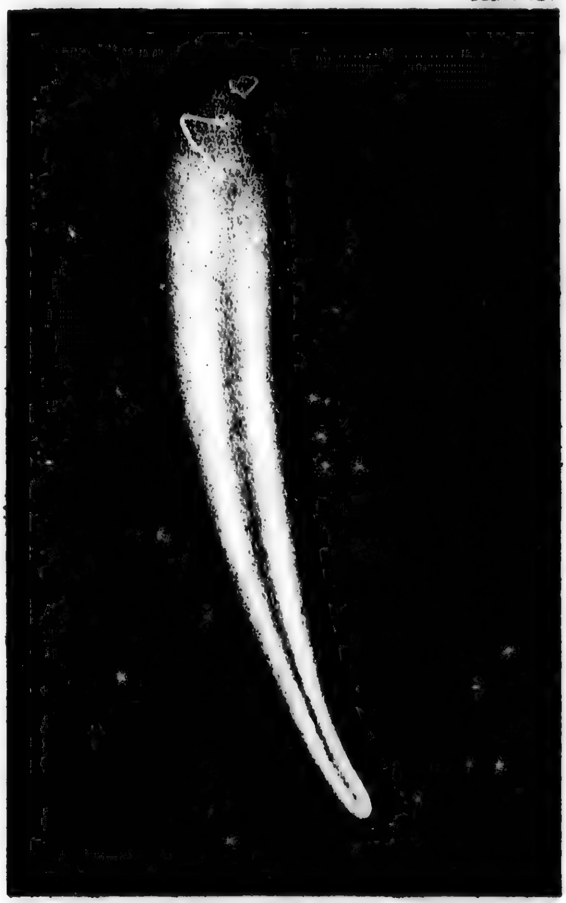
(†) It has been also noticed that "the tails of comets are often somewhat curved; bending, in general, towards the regions which the comet has left, as if moving somewhat more slowly, or as if resisted in their course."

stance which constitutes itself a difficulty in the way of all such hypotheses as have been suggested to explain the luminous cometary characteristics,—or, perhaps it would be more correct to say, which at once negatives those hypotheses,—is thus described (also in the words of Sir John Herschel): "Since it is an observed fact that even those larger comets which have presented the appearance of a nucleus have yet exhibited *no phases*, though we cannot doubt that they shine by the reflected solar light, it follows that even these can only be regarded as great masses of thin vapor susceptible of being penetrated through their whole substance by the sunbeams, and reflecting them alike from their interior parts and from their surfaces. Nor will any one regard this explanation as forced, or feel disposed to resort to a phosphorescent quality in the comet itself, to account for the phenomena in question, when we consider the enormous magnitude of the space thus illuminated, and the extremely small *mass* which there is ground to attribute to these bodies."

In order to give a satisfactory explanation of the appearances thus presented by the comet itself and by the luminous train, which is attached to or accompanies the comet,--an explanation, that is, in harmony with and supported by the observed facts, and by those laws known to govern and regulate the material world,--it is necessary in the first place, to have a definite understanding as to the distinction between a luminous and non-luminous body, and the essential difference between a body which is luminiferous in the sense of emitting, and a body which is luminous in the sense of reflecting. It will be therefore necessary to make a brief but general investigation into the source and nature of that which

FROM DICKS SIDERIAL HEAVENS.

Plate 12.



directly causes the recognized difference between darkness and light.

Note.—We reproduce in the Appendix a part of Sir John Herschel's graphic description of the appearance presented by Halley's comet at the time of its approach and recession in the winter of 1835-36; *and which description applies to the illustrations in Plates* 9 *and* 10.

(9) *Concluding Remarks.*—In treatises on astronomy the student is instructed that the planets belonging to the solar system revolve in orbits which are not circles but ellipses. This circumstance is also usually inculcated and insisted upon as one of the established facts belonging to theoretical astronomy, of the greatest importance.

To such instruction in itself we do not object; but is the instruction carefully defined? and what is the result, as it is usually imparted, on the mind of the student?

We are under the impression that very many persons having some knowledge of astronomy, and, perhaps possessing even a not inconsiderable knowledge of astronomical science, would be astonished and almost shocked if informed suddenly that the above circumstance is true only in a strictly exact (mathematical) sense, and that, speaking in ordinary language to a person not expressly cautioned, the most correct (true) information will be conveyed by stating that the planets revolve in circles and not in ellipses.

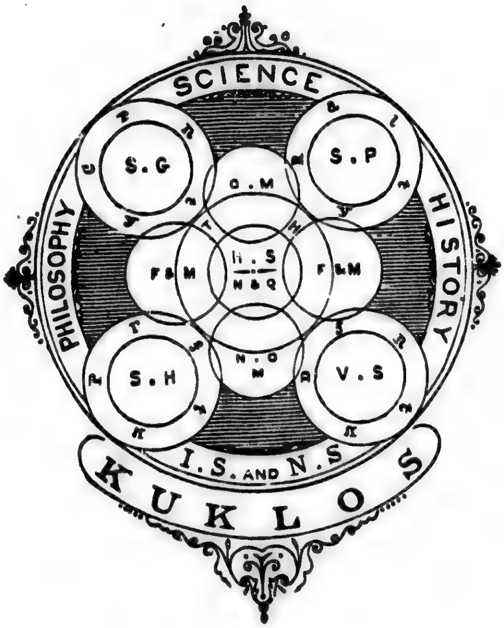
The actual deviation from a true circle is perfectly well known and correctly taught in all sound works on astronomy, nevertheless, illustrations are constantly put before the student in which the very small actual ellipticity is enormously exaggerated without a word of caution that it is so.

The following statement, in the words of *Dr. Lardner*, distinctly defines the actual amount of deviation from a circle.

"The orbits of the planets generally are ellipses, but having eccentricities so small that, if described on a large scale in their proper proportions on paper, they could be distinguishable from circles only by measuring accurately the dimensions taken in different directions, and thus ascertaing that they are longer in a certain direction than in another at right angles to it."

In concluding our present examination of this subject. we will leave in the hands of the reader the two following questions which pertinently suggest themselves in this connexion.

(1)... Is there any reasonable ground whatever for believing or supposing that a comet differs in *its nature* from a planet, to wit: that, a planet being a mass of aggregated matter, a comet differs therefrom in kind, and is immaterial? (2)... Since a planet, subjected to perturbing and interfering causes, is unable in any case to deviate from a circle more than to a very slight and scarcely appreciable extent, how are we to accept a proposition that a comet, if it be a body of the same nature and subject to the same laws, may choose its orbit in the most capricious manner out of several figures, and not only deviate immensely from a circle but may, if it please, suddenly discard altogether the influence and control of the sun, and depart from the solar system in a direct line?


SCIENCE
PHILOSOPHY
HISTORY
S.G
S.P
O.M
F&M
H.S
N&Q
F&M
N.O
M
S.H
V.S
I.S. AND N.S
KUKLOS

APPENDIX.

See Plates 9 and 10. " Although the appearance of this celebrated comet at its last apparition was not such as might be reasonably considered likely to excite lively sensations of terror, even in superstitious ages, yet, having been an object of the most diligent attention, in all parts of the world to astronomers, furnished with telescopes very far surpassing in power those which had been applied to it at its appearance in 1759, and indeed to any of the greater comets on record, the opportunity thus afforded for studying its physical structure, and the extraordinary phenomena which it presented when so examined have rendered this a memorable epoch in cometic history. Its first appearance, while yet very remote from the sun, was that of a small round or somewhat oval nebula, quite destitute of tail, and having a minute point of more concentrated light within it. It was not before the 2nd of October that the tail began to be developed, and thenceforward increased pretty rapidly, being already 4° or 5° long on the 5th. It attained its greatest apparent length (about 20°) on the 15th of October. From that time, though not yet arrived as its perihelion, it decreased with such rapidity, that already on the 29th it was only 3°, and on November the 5th, 2½° in length. There is every reason to believe that before the perihelion, the tail had altogether disappeared, as, though it continued to be observed at Pulkowa up to the very day of its perihelion passage, no mention whatever is made of any tail being then seen."

"By far the most striking phenomena, however, observed in this part of its career, were those which, commencing simultaneously with the growth of the tail, connected themselves evidently with the production of that appendage and its projection from the head. On the 2nd of October (the very day of the first observed commencement of the tail) the nucleus, which had been faint and small, was observed suddenly to have become much brighter, and to be in the act of throwing out a jet or stream of light from its anterior part, or that turned *towards* the sun. This ejection after ceasing awhile was resumed, and with much greater apparent violence, on the 8th, and continued, with occasional intermittances, as long as the tail itself continued visible. Both the form of this luminous ejection, and the direction in which it issued from the nucleus, meanwhile underwent singular and capricious alterations, the different phases succeeding each other with such rapidity, that on no two successive nights were the appearances alike. At one time the emitted jet was single, and confined within narrow limits of divergence from the nucleus. At others it presented a fan-shaped or swallow-tailed form, analogous to that of a gas-flame issuing from a flattened orifice: while at others again, two, three, or even more jets were darted forth in different directions. (See figs. *a*, *b*, *c*, *d*, plate IV.) which represent, highly magnified, the appearance of the nucleus with its jets of light, on the 8th, 9th, 10th, and 12th of October, and in which the direction of the anterior portion of the head." * * * * * "The direction of the principal jet was observed meanwhile to oscillate to and fro on either side of a line directed to the sun in the manner of a compass needle when thrown into

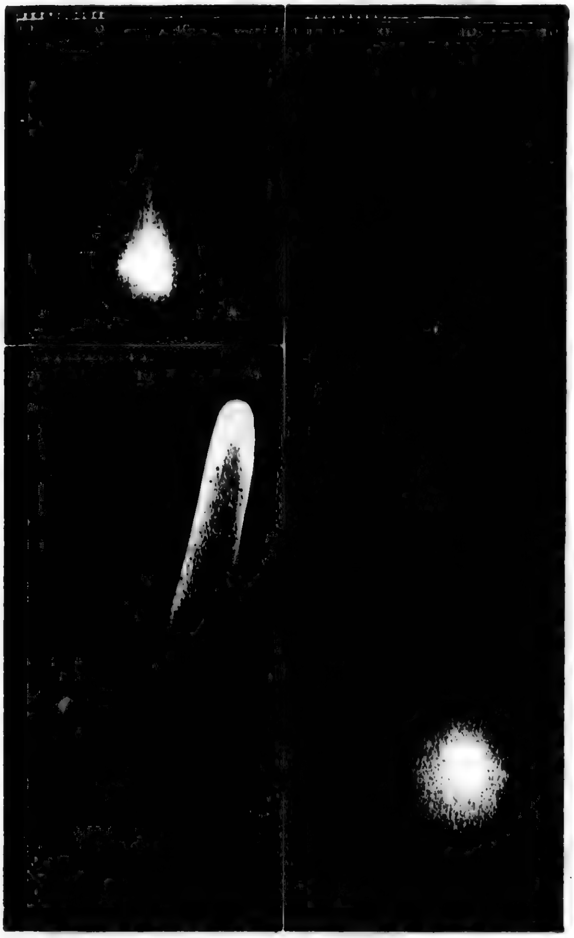
vibration and oscillating about a mean position, the change of direction being conspicuous even from hour to hour. These jets, though very bright, at this point of emanation from the nucleus, faded rapidly away, and became diffused as they expanded into the coma, at the same time curving backwards as streams of steam or smoke would do, if thrown out from narrow orifices, more or less obliquely in opposition to a powerful wind, against which they were unable to make way, and ultimately yielding to its force, so as to be drifted back and confounded in a vaporous train, following the general direction of the current." * * * * "After the perihelion passage, the comet was lost sight of for upwards of two months, and at its reappearance (on the 24th of January, 1836) presented itself under quite a different aspect, having in the interval evidently undergone some great physical change which had operated an entire tranfonmation in its appearance. It no longer presented any vestige of tail, but appeared to the naked eye as a hazy star of about the fourth or fifth magnitude, and in powerful telescopes as a small, round, well defined disc. rather more than 2′ in diameter, surrounded with a nebulous *chevelure* or coma of much greater extent. Within the disc, and somewhat eccentrically situated, a minute but bright nucleus appeared, from which extended towards the posterior edge of the disc or (that remote from the sun) a short vivid luminous ray. (See Figure, Plate 10.) As the comet receded from the sun, the coma speedily disappeared, as if absorbed into the disc, which on the other hand, increased continually in dimensions, and that with such rapidity, that in the week elapsed from January 25th to February 1st

(calculating from micrometrical measures, and from the known distance of the comet from the earth on those days) the actual volume or *real solid content* of the illuminated space had dilated in the ratio of upwards of 40 to 1. And so it continued to swell out with undiminished rapidity, until, from this cause alone, it ceased to be visible, the illumination becoming fainter as the magnitude increased; till at length the outline became undistinguishable from simple want of light to trace it. While this increase of dimension proceeded, the form of the disc passed, by gradual and successive additions to its length in the direction opposite to that of the sun, to that of a paraboloid, as represented in the figure. It is evident that had this process continued with sufficient light to render the result visible, a tail would have been ultimately reproduced; but the increase of dimension being accompanied with diminution of brightness, a short, imperfect and as it were rudimentary tail only was formed, visible as such for a few nights to the naked eye, or in a low magnifying telescope, and that only when the comet itself had begun to fade away by reason of its increasing distance." While the parabolic envelope was thus continually dilating and growing fainter, the nucleus underwent little change, but the ray proceeding from it increased in length and comparative brightness, preserving all the time its direction along the axis of the paraboloid, and offering none of those irregular and capricious phenomena which characterised the jets of light emitted anteriorly, previous to the perihelion. If the office of these jets was to feed the tail, the converse office of conducting back its successively condensing matter to the nucleus would seem to be that of the ray now in ques-

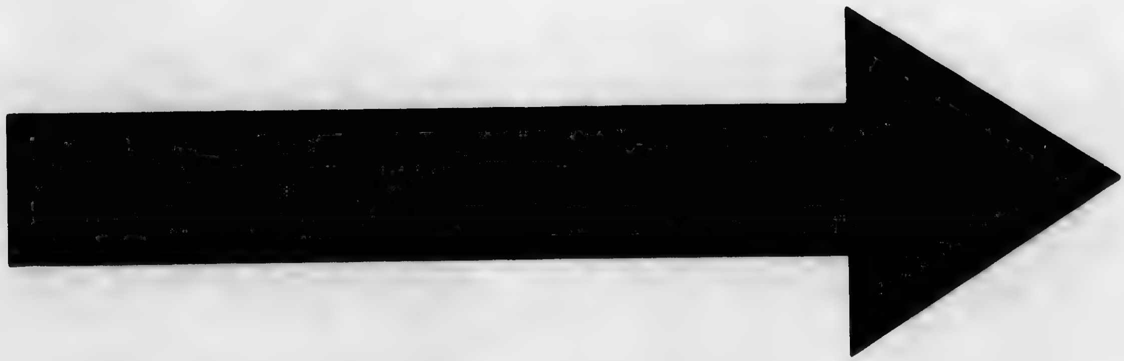
HALLEY'S COMET, 1835

APPROACHING THE SUN TELESCOPIC DRAWINGS BY STRUVE

Plate 9.



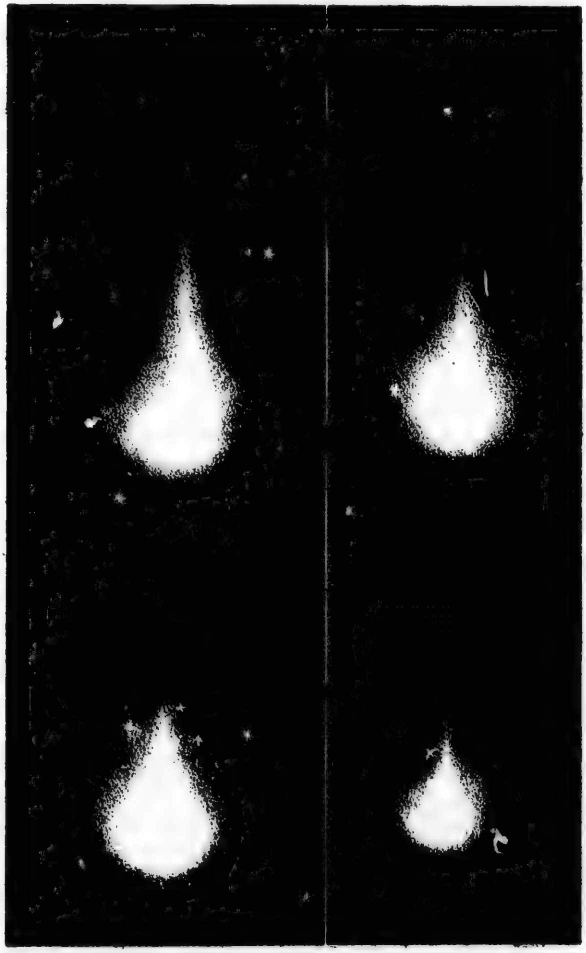
1.Sep.29 2.Oct.3. 3 Oct 29.




2.8
2.5
3.2
2.2
2.0
1.0

HALLEY'S COMET DEPARTING FROM THE SUN IN 1836

Plate 10.



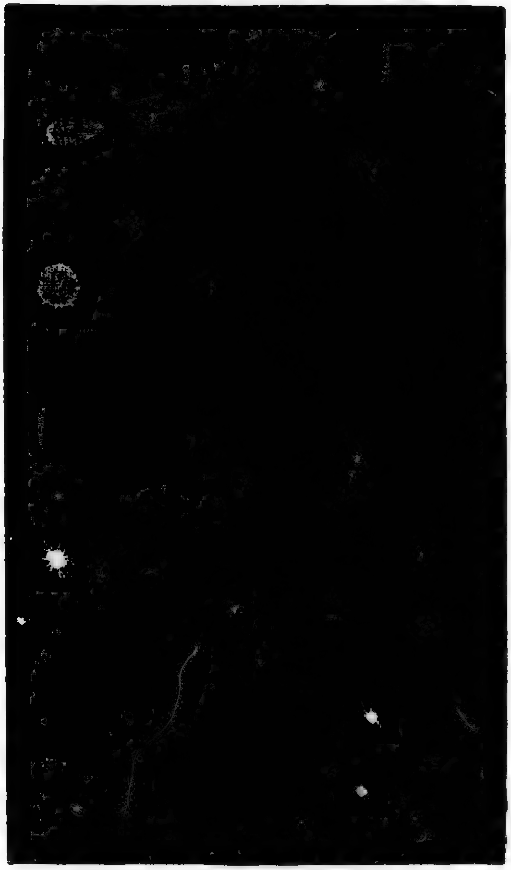
1. Feb. 7. 2. Feb. 10. 3. Feb. 16. 4. Feb. 23.

tion. By degrees this also faded, and the last appearance presented by the comet was that which it offered in its first appearance in August; viz: that of a small round nebula with a bright point in or near the centre."

Plate 14. (Frontispiece.) *Encyclopedia Britannica.*— "Fig. 106 is a representation of the celebrated comet of 1680, taken from Lemonnier's *Histoire Céleste*. It exhibits the nucleus or disk with its surrounding atmosphere. Above is a sort of ring, wider at the summit and narrower towards the sides. A *coma* or beard succeeds the ring; and lastly, an immense train of luminous matter, somewhat less vivid than the nucleus. This luminous train, or tail as it is called, is by far the most singular and striking figure presented by the comets. That of the comet of 1744 was one of the most remarkable. It was divided into six branches all diverging, but curved in the same direction; and between the branches the stars were visible." It is represented in Figure 107, Plate 14.

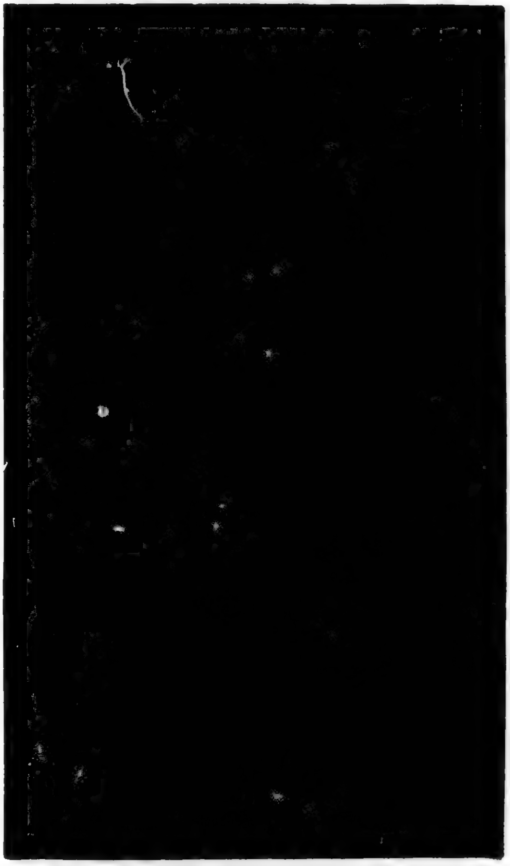
From Dick's Siderial Heavens.

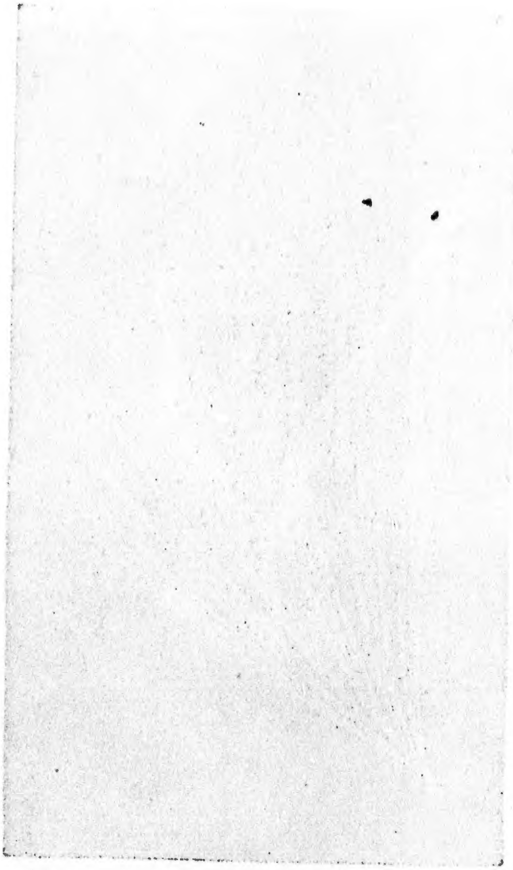
PLATE II.



From Dick's Siderial Heavens.

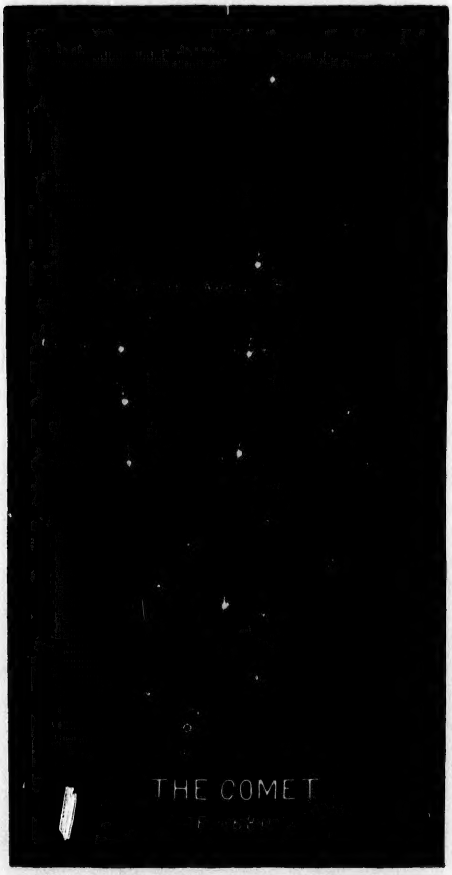
PLATE 13.





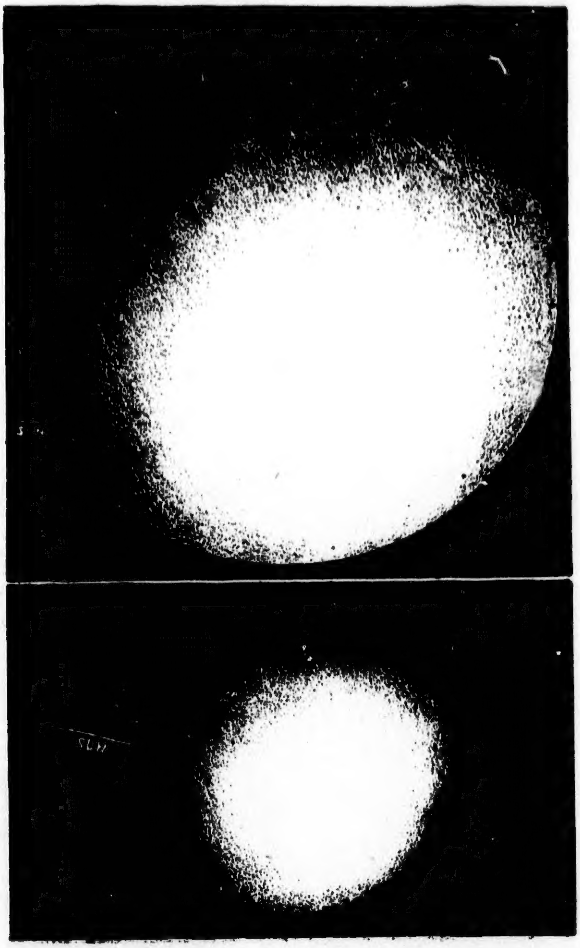
From Dick's Siderial Heavens.

PLATE 14.



ENCKE'S COMET, 1828.

Plate 17



1 Nov. 7. 2 Nov. 30.